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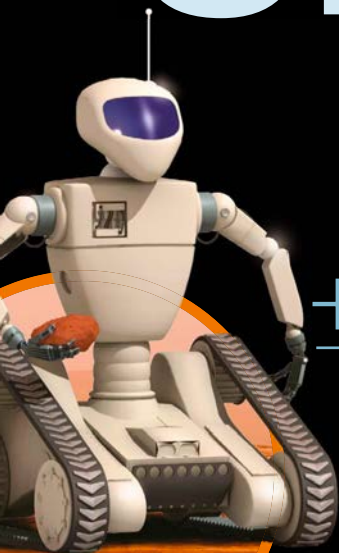
Future

ISSUE 062

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**BEAT LIGHT
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Welcome to issue 62

This month, we take a trip to the very edge of the universe to find out what could exist beyond

its confines. Some believe that our cosmos was born out of a black hole, with its end taking the form of an event horizon (the point of no return), while others think we could be touching one of many universes that make up a so-called multiverse. According to data from NASA missions past and present, astronomers have their suspicions as to what could exist beyond the countless stars and galaxies. This issue, make sure you turn to page 16 to uncover what the likely scenario is.

Of course, the universe is continually throwing questions at us, some of which we're still trying to find the answers to. No one knows this better than the scientists trying to

figure out the mystery of Tabby's Star - commonly, and perhaps incorrectly, referred to as the 'megastructure star'. This month we meet the astronomers who are debunking the myths behind space's strangest star and offering explanations for its behaviour - from planetary consumption to a belt of fast-moving comets.

I know that some of you live in light-polluted areas, which makes observing the night sky incredibly difficult. For those of you who are struggling to see the planets or are keen to see the Andromeda Galaxy from less than ideal skies, this issue we show you how to observe your favourite objects from towns and cities. See you again on 30 March!

Gemma Lavender
Editor

Contributors

Luis Villazon



Human space exploration is a challenging enterprise. Luis seeks out the solutions to the problems involved in sending humans into deep space. Turn to page 26 for some impressive technology.

Giles Sparrow



Mercury is shrinking! Giles speaks to the scientists with proof that the tiny world is getting even smaller and explores what it may mean for its fate. Could the Solar System lose a planet?

Paul Cockburn



The famously-weird 'megastructure star' is still puzzling astronomers - but they may be getting closer to discovering what is causing its strange behaviour, as Paul discovers.

Jaspal Chadha



No stranger to observing and imaging from towns and cities, Jaspal shows you how to beat light pollution and observe the many treasures of the night sky, without travelling to a dark sky site.

Spectacular views of astronomical objects can still be had in light-polluted areas with a little know-how

"If you're looking to observe into deep space, it's best to wait until a Moonless night to avoid adding more interference"

Beat Light Pollution Tonight [Page 70]

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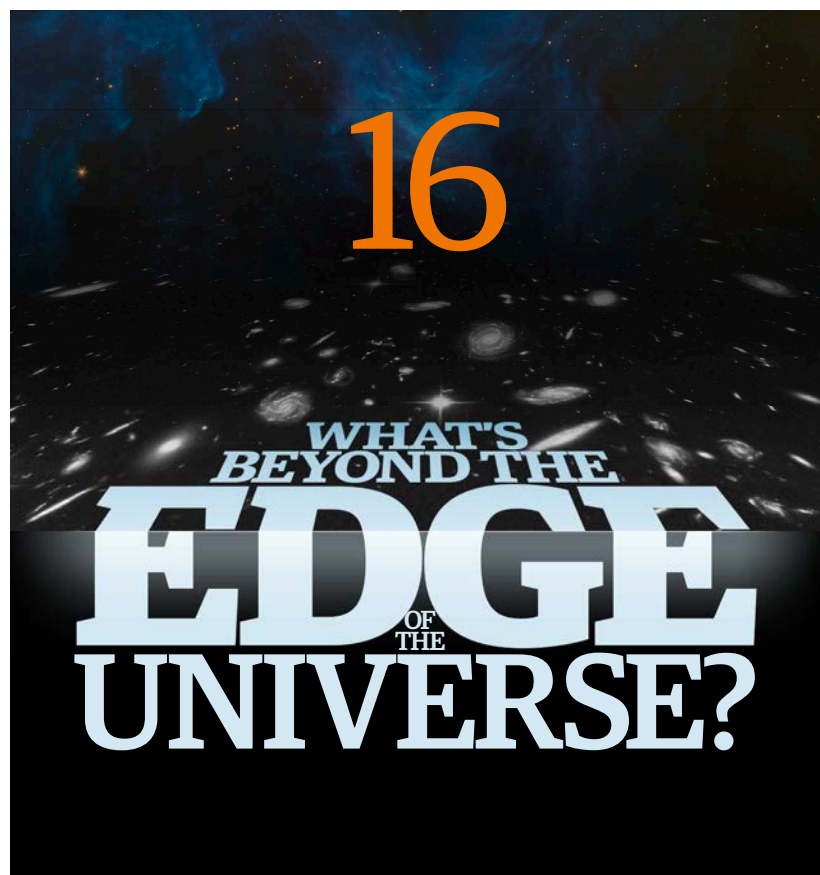
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The largest moon of Pluto, Charon is an imposing celestial mystery all on its own

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"The great thing about the EmDrive is that it carries no fuel. It would make interstellar travel possible"

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Physicist at Plymouth University

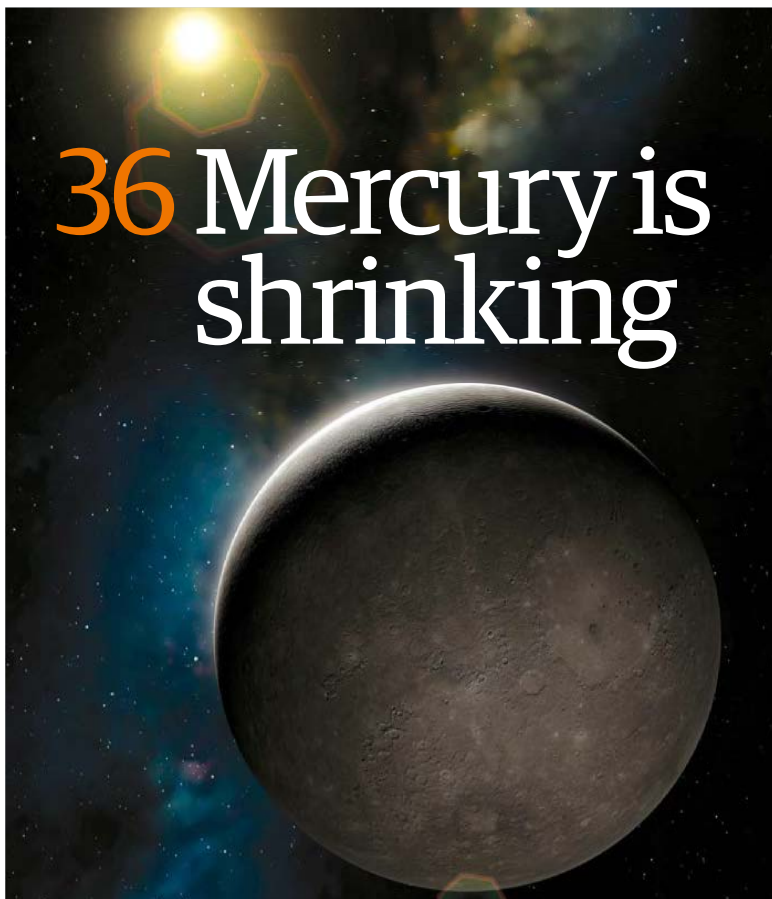
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Starbirth with a chance of winds

Home to a variety of deep-sky objects, the constellation Canes Venatici (The Hunting Dogs) is home to this beautiful galaxy known as NGC 4861. Perhaps unsurprisingly, astronomers are finding it difficult to classify this astronomical object: its mass, size and rotation speed indicate that NGC 4861 is a spiral galaxy, while its appearance is quite similar to a comet – a feature that puts it in the dwarf irregular galaxy category. NGC 4861's messy appearance provides astronomers with opportunities to investigate galactic winds that flood these structures. The process of star formation, which involves huge amounts of energy, powers galactic winds, and baby stars are springing into life within the galaxy's bright, colourful head.



In the wind tunnel of engine designs

NASA and the aircraft industry are hoping to improve fuel efficiency of aircraft design. This is the view of a wind tunnel at NASA Glenn Research Center where engineers recently tested a fan design, commonly called a propulsor, which could use four to eight per cent less fuel than today's advanced aircraft. The new propulsor has been designed to be embedded in the aircraft's body, where it ingests the slower air - known as the boundary layer - and uses it to help propel the craft forward. Tests revealed that the new fan and design could indeed increase efficiency.

@NASA

A slice of Sagittarius

The Hubble Space Telescope took this image of a section of the constellation of Sagittarius (The Archer). Deep red and bright blue stars are scattered across the frame and are set against a background of thousands of more distant stars and galaxies. Stars differ in colour due to their surface temperature: very hot stars are blue or white, while cooler stars are redder. The 'crosses' on the stars aren't a feature of the stars themselves - called diffraction spikes - they are actually caused by Hubble's structure where incoming light is bent.

@ESO, Hubble, NASA



Mars' lava fields

Narrow rock ridges, some as tall as a 16-story building, intersect at angles to form the corners of polygon shapes. This image in particular covers an area that spans about 1.1 kilometres (0.7 miles) in the Medusae Fossae region of the Red Planet. Taken by the High Resolution Imaging Science Experiment (HiRISE) camera on the Mars Reconnaissance Orbiter, these ridges were likely formed by lava that hardened underground and later resisted erosion.

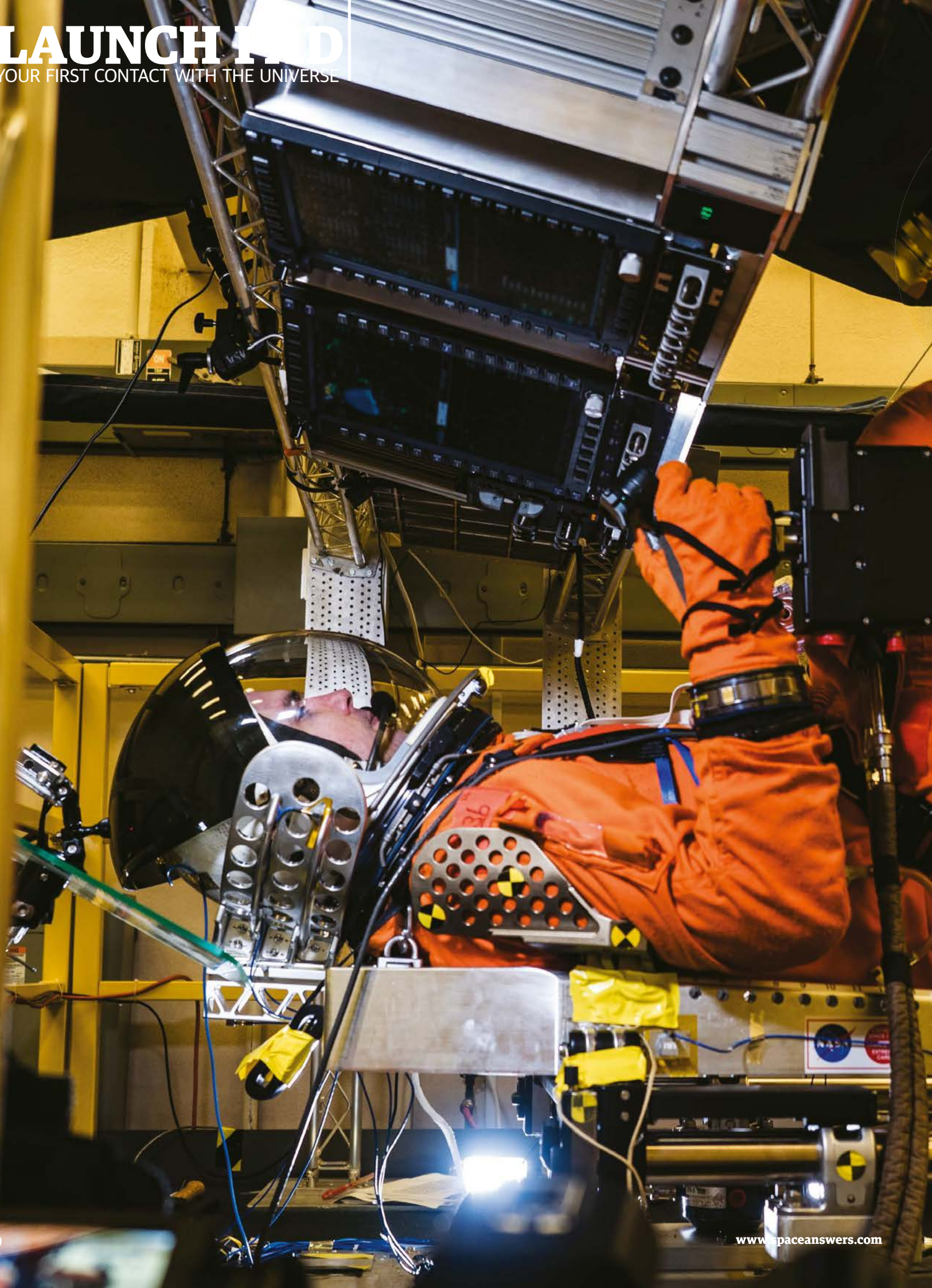
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ALMA looks to the skies

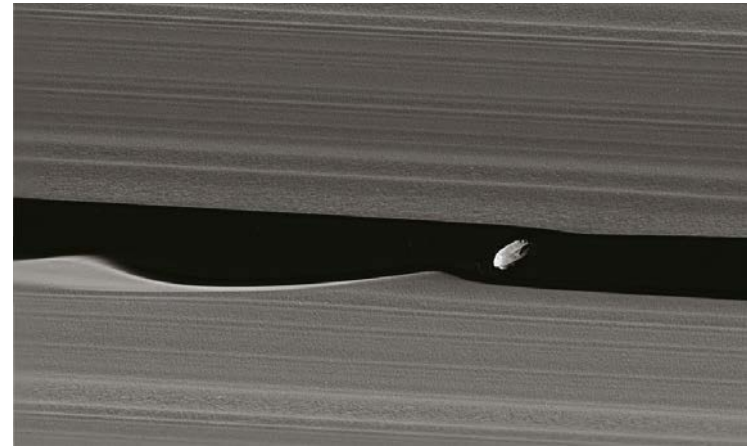
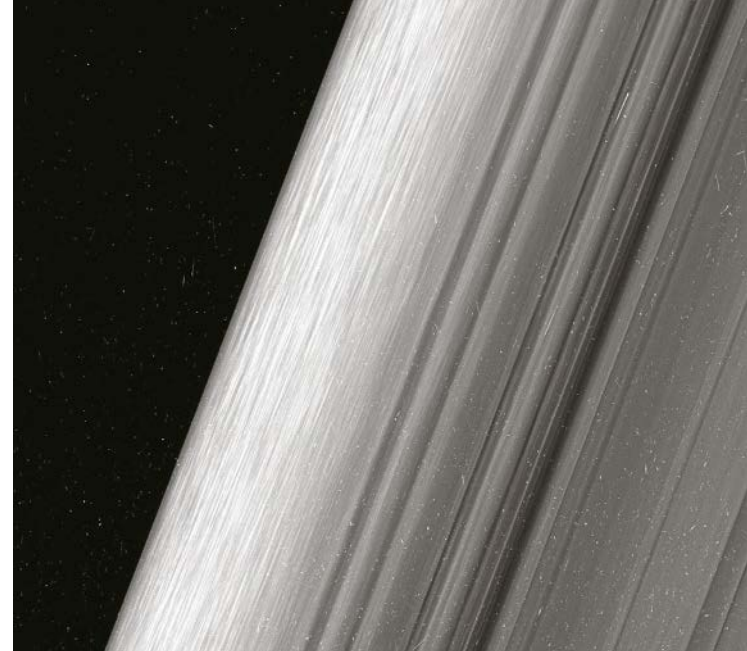
Comprising of 66 high-precision radio telescopes with diameters of 12-metres (39.3 feet) and seven-metres (23 feet), spread over the Chajnantor Plateau in the Atacama Desert in northern Chile, the Atacama Large Millimeter/submillimeter Array (ALMA) looks up to a blue sky that's covered in thin, wispy clouds. ALMA, which has been fully operational since March 2013, is elevated at 5,000 metres (16,404 feet). This is a perfect location for telescopes as it is free of atmospheric interference and provides insight on the birth of stars and the early universe. The array also conducts detailed imaging of local star and planet formation.

@ESO/J. C. Rojas



NASA simulates an Orion spacecraft launch

Inside a lab at NASA's Johnson Space Center in Houston, Texas, engineers simulated the conditions future astronauts would experience when the Orion spacecraft launches atop the powerful Space Launch System. It forms one of many in a series of tests that will help us to assess how well the crew can interact with the displays and controls used to monitor and operate Orion's systems. 'Test astronauts' wore modified advanced crew escape suits, which are currently being developed, and sat in the latest design of the Orion spacecraft's seats. Orion's late 2018 mission will be uncrewed, with crewed missions set for launch as early as 2021.



Cassini's close up of Saturn's rings

Now in its ring-grazing orbit phase at Saturn, NASA's Cassini spacecraft captures the ringed planet's dazzling rings of icy debris in unprecedented detail. The views are some of the closest-ever images of the outer parts of the main rings, providing astronomers with the opportunity to observe 'straw' and 'propeller' features. Cassini is now over halfway through its penultimate mission phase, which consists of 20 orbits that dive past the outer edge of the main ring system. The ring-grazing orbits began last November and will continue until late April, where Cassini will repeatedly plunge through the gap between the rings and Saturn. Its first grand finale dive will occur on 26 April.

© NASA, JPL-Caltech; Space Science Institute

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YOUR FIRST CONTACT WITH THE UNIVERSE

NASA release new results from twin astronaut experiment

Key ageing processes appeared to reverse when astronaut Scott Kelly lived on the ISS

“Scott Kelly’s telomeres had actually increased while in space”

An astronaut who lived in space for just under a year appeared to temporarily reverse his ageing processes, according to brand new research. Scott Kelly, who spent 340 days on the International Space Station between 2015 and 2016, had noticeable mutations in his DNA that appeared to fly in the face of scientific expectations.

One group of investigators looked within Scott’s white blood cells and specifically at his telomeres, which appear at the end of chromosomes. These are known to decrease in length as a person gets older, yet radiation biologist Susan Bailey found the astronaut’s telomeres had actually increased while he was in space.

They ended up being longer than those of his twin brother, Mark, who had spent the entire period with his feet firmly on Earth. “That is exactly the opposite of what we thought,” Bailey says. She

believes the change could be linked to Scott’s increased exercise and reduced diet while on board the International Space Station. The telomeres began shortening once more when he returned, however.

NASA also says that telomerase activity also increased in both Scott and Mark Kelly last November. This relates to an enzyme that repairs the telomeres and lengthens them, and Bailey believes that this may have been caused by a particularly stressful event in both the twins’ lives at that time. If, however, being in space for a significant amount of time does appear to reverse ageing in some way, it would be of major importance for long-duration missions.

The preliminary findings are a result of NASA’s Human Research Program and, more specifically, the Twins Study. Mark, a retired astronaut, was the ground-based control for the experiments and

biological samples from both brothers are still being studied by ten researchers, who are keen to discover the effects an extended time in space can have on the body. Mathias Basner’s study of cognitive performance, for example, found Scott suffered a slight decrease in speed and accuracy post-mission but that the difference between spending six or 12 months in space is negligible.

There also appeared to be a decline in bone formation during Scott’s final six months in orbit, although there was good news in relation to a flu vaccine: jabs for each twin showed an increase in T cell receptors, which was the expected immune response. Chemical modifications to Scott’s DNA were seen to decrease while he was in space, however, indicating that genes are very sensitive to a changing environment. Studies are continuing with more findings due to be released later this year.

Bus-sized asteroid hurtles past Earth

Speedy space rock 2017 BS32 may have been 161,280 kilometres (100,214 miles) away from Earth when it zoomed past on 2 February 2017, but the bus-sized object was a fascinating sight for astronomers across the world, who had only spotted it a couple of days earlier. It was the fourth near-Earth asteroid to arrive this year, and certainly won't be the last.

Space Shuttle Challenger's lost football finally reaches space

A football that was on the Space Shuttle Challenger, which tragically exploded 73 seconds after lift-off on 28 January 1986, has finally made it into orbit. Recovered from the wreckage in the Atlantic Ocean 30 years ago, astronaut Shane Kimbrough took it with him on his current mission to the International Space Station.

Animal beachings could be caused by solar storms

Scientists trying to work out why whales, dolphins and porpoises become beached on coastal land - such as the 400 whales recently found in New Zealand - say the cetaceans' magnetic-field sensing, which is used for navigation, may be getting confused and distorted by solar storms. NASA researchers are now carrying out a study into the phenomena and they hope to share the results in September.

Japanese 'space junk craft' falls to Earth

A Japanese cargo spacecraft testing a new way of removing space junk from our planet's orbit failed and fell back towards the Earth. Having delivered its supplies to the International Space Station, the spacecraft tried in vain over many hours to use a tether to grab orbital debris, but ended up being intentionally burned up in the Earth's atmosphere.

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There are thought to be millions of black holes in the Milky Way

Quiet black hole found hiding in the Milky Way

Scientists have accidentally discovered a way of identifying exotic objects within our galaxy

Astronomers say they have found hints of a wandering black hole lurking in a corner of our galaxy. This so-called "quiet black hole" was spotted by analysing the gas motion of an unusual, fast-moving cosmic cloud, and it points to an exciting new method of discovery.

Since they don't interact with nearby stars like normal black holes, these sneaky, lonely celestial objects have largely evaded observation; that is why only a few dozen black holes have been found so far yet there are believed to be millions of them floating alone in the Milky Way.

A Japanese research team using the ASTE Telescope in Chile found

the particular quiet black hole in question. They were looking for molecular clouds some 10,000 light years away around the supernova remnant W44, and were trying to see how much energy had transferred from the supernova explosion to the surrounding molecular gas. However, the team accidentally came across this strange moving cloud, which they dubbed the 'Bullet'.

Moving at more than 100 metres (328 feet) per second, it was also seen to move backwards against the rotation of the galaxy. To explain this, the team proposed a dark, compact gravity source was to blame, which points to it coming under the

influence of a black hole. This black hole is either static, in which case it is pulling the gas towards it - causing an explosion that comes into our line of sight - or it is moving and thereby dragging the gas with it.

"Most of the Bullet has an expanding motion with a speed of 50 kilometres (31 miles) per second, but the tip of the Bullet has a speed of 120 kilometres (75 miles) per second," says Masaya Yamada, a graduate student at Keio University, Japan. "Its kinetic energy is a few tens of times larger than that injected by the W44 supernova. It seems impossible to generate such an energetic cloud under ordinary environments."

Alien life may be hiding under rocks on Mars

Microbes elsewhere in the Solar System could be closer than we initially thought

Iron oxides coating the surface of rocks on the Red Planet may be acting as an ultraviolet sunscreen for microbial organisms. At least, that's the theory being put forward by chemical and planetary scientist Janice Bishop, who found that carbonate organisms in the Mojave Desert in California were being protected from deadly ultraviolet light back in 2011.

Bishop, who works with the Search for Extraterrestrial Intelligence Institute (SETI), believes a common



Do rocks on Mars hide the secret of alien life on the Red Planet?

Martian surface element called hematite shielded bacterial alien life in the distant past, just as it did on Earth. This allowed for photosynthesis, converting light into chemical energy.

The theory has led to much research in this scientific area, with a common eagerness to find out how microbes evolved on Earth during the period when there was no protective ozone layer. Should scientists crack that, it will go some way to explaining how life could exist on a planet with

similar current circumstances. Among those studying this new sunscreen concept is Gozen Ertem from the University of Maryland.

Ertem is looking at how well biomolecules can hide from ultraviolet radiations in different mixtures. Even so, Bishop - who believes curiosity about how life evolved on Mars will reveal much about Earth - doesn't believe there is life on the Red Planet today, and states it's "kind of a stretch" to suggest otherwise.

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Odd supernova challenges theory of how stars evolve

NuSTAR has uncovered fresh clues about the behaviour of the 'chameleon supernova'

Astronomers say the star may have been part of a binary system, influencing its evolution



If helium is reactive, it opens up research avenues for those studying gas giants

Gas giants' new helium compound

Maybe helium is not an inert gas after all, potentially marking a new frontier of chemistry

It appears that our perceived wisdom may be wrong: helium could well be capable of forming stable compounds with other elements. It has long been thought that helium was a noble gas - it doesn't bond readily with other elements - but a team of scientists are on the verge of rewriting the textbooks.

Researchers have created a thermodynamically stable compound of helium and sodium. More importantly, they did it at the kinds of high pressure found within the gas giant planets. With helium being so abundant in gas giants and stars, the result is going some way to better understanding the high-pressure centre of Jupiter, Saturn, Uranus and Neptune. "One more traditional assumption has fallen," says Artem Oganov of Stony Brook University, NY. Researchers used an algorithm and high-pressure synthesis in a diamond anvil cell, and the results predicted a compound of one helium and two sodium atoms, as well as a compound of one helium, two sodium and one oxygen atom.

A 'chameleon supernova' is challenging models of star evolution. Scientists studying SN 2014C have noted vast changes in its appearance over the course of a year, which they say is due to the star having unusually released a huge mass of material late in its life. Since this happened in the decades to centuries before the star exploded, it is altering models of how stars distribute their elements following a violent death.

Typically there are two types of exploding stars. Type I refers to

supernovae that have no hydrogen present during the event. In these cases, the gas has run out thanks to the star beginning its life fusing hydrogen into helium. Type II supernovae have an abundance of hydrogen but they are much more rare. Yet SN 2014C - found in a spiral galaxy 36 to 48 million light years away - differs from these models.

Astronomers say it transformed from a Type I to a Type II after its core collapsed. The conclusion was made by Raffaella Margutti, assistant

professor of physics and astronomy at Northwestern University, Illinois, who observed the supernova with NASA's NuSTAR (Nuclear Spectroscopic Telescope Array) satellite. She observed radiation in the X-ray energy range and watched the temperature of electrons accelerated by the supernova shock over time.

"This 'chameleon supernova' may represent a new mechanism of how massive stars deliver elements created in their cores to the rest of the universe," she says.

Rapid gas flares discovered on white dwarfs

Oxford scientists reveal that our understanding of star habits is incomplete

Scientists at Oxford University, UK, have detected rapid gas flares emitted by a white dwarf system for the first time. They were observed in the binary system SS Cyg, which is one of the brightest variable stars in the constellation Cygnus, and they were due to an enormous amount of energy suddenly being released.

Low-level bursting behaviours, or outbursts, have been detected in dwarf novae in the past but never on the scale of rapid flares, seen as fast variations in brightness. A giant flare was observed that lasted 15 minutes, said to have the energy of more than 1 million times the strongest solar flares.

Lead researcher Dr Kunal Mooley, astrophysics research fellow at Oxford University, says: "Many of astrophysics' most compelling studies have been based on studying SS Cyg. The latest, a detection of a rapid radio flare, is highly unusual and demonstrates there may even be some new physics at play. We expected to see slow variation flares but found fast, rapid, cone-like spikes of activity and



SS Cyg was discovered more than 100 years ago and is 372 light years away

observed an enormous amount of energy being released in ten minutes. Nothing like this has ever been seen before in a dwarf nova system."

Usually outbursts in white dwarfs, neutron stars and black holes are due to these stars feeding on gas from their companion stars through accretion,

which is when large amounts of gas accumulates through gravitational force. The unusual activity in SS Cyg, however, defies the understanding of gas accretion and flare production in binary stars. Work is now continuing, in a bid to discover why the rapid flares occurred.

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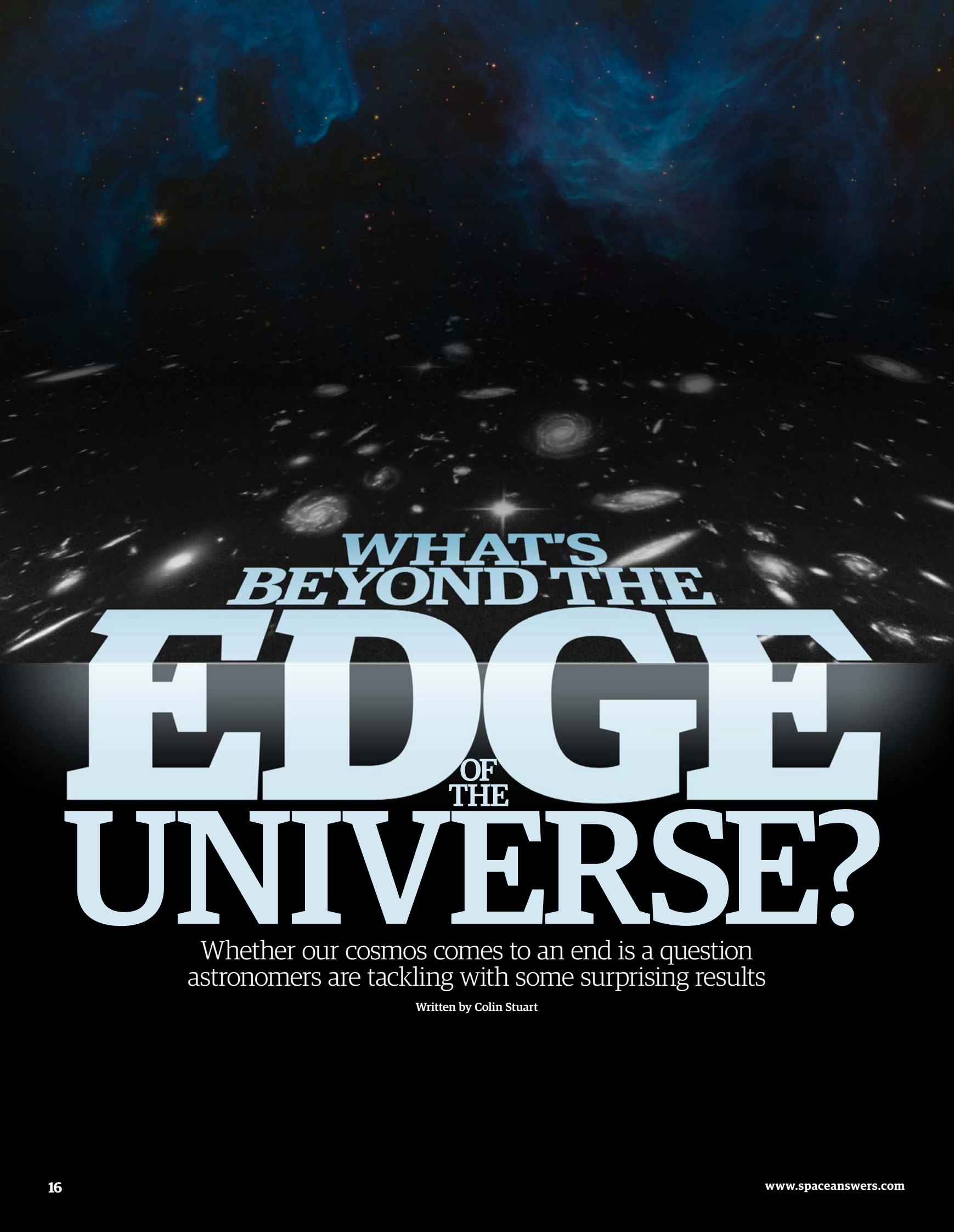
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A deep space background featuring a dense field of galaxies, including spiral and elliptical shapes, and vibrant blue nebulae. The text is overlaid on this cosmic scene.

WHAT'S BEYOND THE EDGE OF THE UNIVERSE?

Whether our cosmos comes to an end is a question
astronomers are tackling with some surprising results

Written by Colin Stuart

Look out on a clear night and you can see pretty far into the universe. Some of the stars you'll spot will sit over 10,000 light years from the Earth - that's nearly a billion trillion metres away. Even further away is the famous Andromeda galaxy, the nearest major star-city to our own Milky Way and debatably the most distant object you can see with your eyes alone. It is located a staggering 2.5 million light years away from us. That means the light arriving on Earth today from Andromeda has been trekking across space for 2.5 million years to get here. All of human history has played out in the time it's taken for light to reach us from just our nearest galaxy. With binoculars and telescopes you can continue

to see objects further and further from home. But where does it all end? Does it even end?

"We just don't know," says Andrew Pontzen, a cosmologist at University College London. "There is no evidence for an edge to the universe, but there is an edge to what we can see." We can only see objects in space if the light from those objects has had enough time to reach us. For Andromeda, that time is 2.5 million years, but for increasingly more distant galaxies, that light travel time also increases. There are some galaxies so far away that light hasn't managed to make it here yet in the nearly 14 billion years since the Big Bang. This marks out the edge of our visible universe - the part of it we are able to see

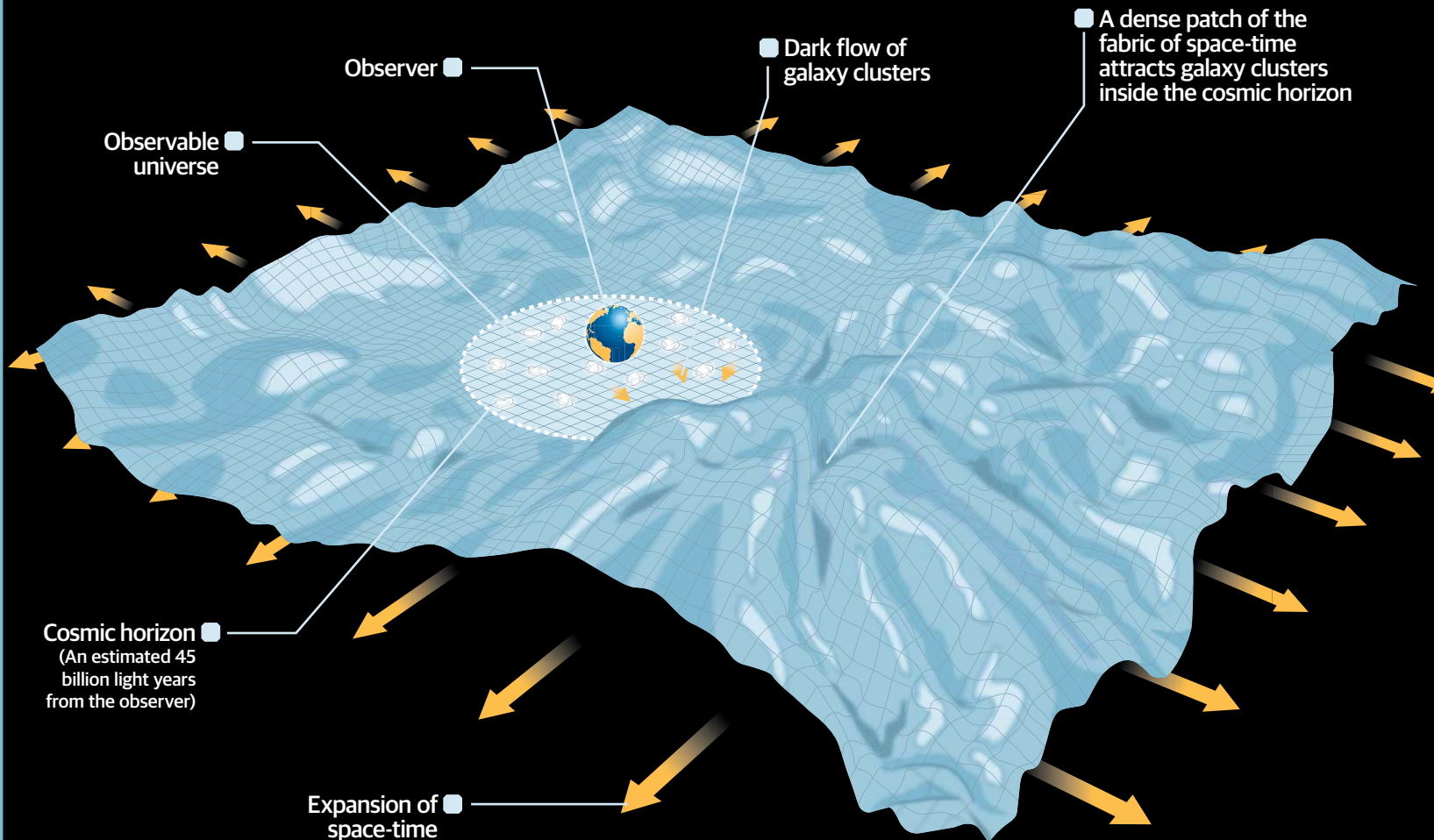
- but not the end of the universe itself. "It's rather like how you can't see over the horizon but the Earth doesn't end there," Pontzen says. So, in theory, each passing day should bring with it new light allowing us to push our cosmic horizon outwards. Yet it doesn't quite work like that.

"The longer you wait, the further you should be able to see," says Pontzen. "However, the expansion of the universe is beginning to speed up quite noticeably because of the mysterious stuff we call dark energy." This increased expansion is carrying parts of the distant universe ever more quickly away from us and there will come a point when we'll have seen as far as we'll ever be able to see. But what is likely to be beyond that visible horizon? Well, quite possibly more of the same. Some astronomers subscribe to the idea of an infinite universe - one that continues on forever with no edge or boundary. Just more stars and more galaxies. And that has led some to perhaps a rather disturbing conclusion - that there could be exact copies of you out there

"There will come a point when we'll have seen as far as we'll ever be able to see. But what lies beyond the visible horizon?"

The edge of the universe

Wayward galaxy clusters, which appear to be pulled in one direction by 'dark flow', could give us the first hint of something beyond the cosmic horizon



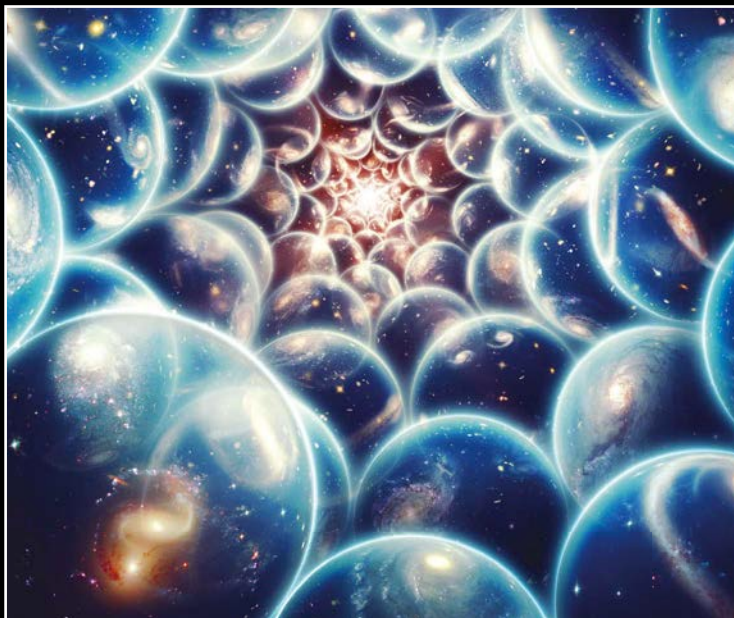
What's at the edge?

Cosmologists have put forward several different scenarios for where our universe ends



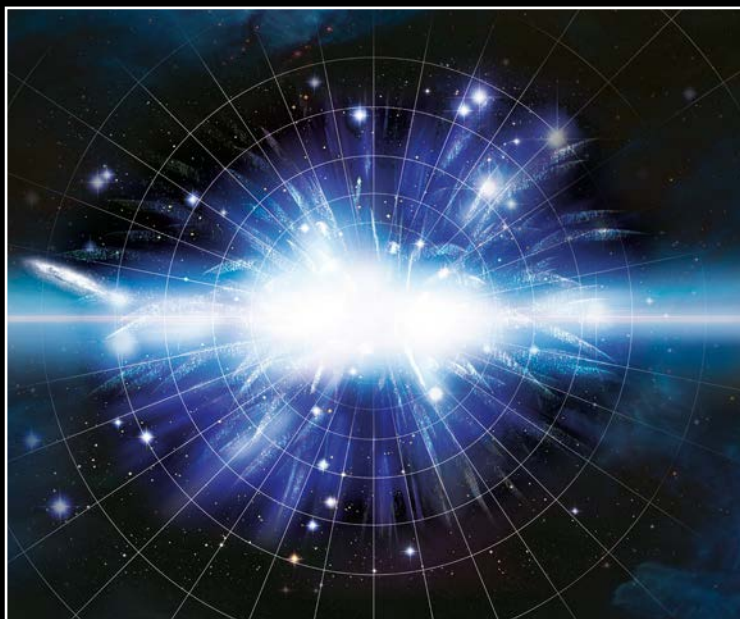
The universe goes on forever

The universe could be infinite in extent, endlessly continuing in all directions, on and on beyond our cosmic horizon, with no edges or boundaries. If this picture is accurate then the universe has no edge, and it gives rise to the idea that eventually the same configuration of atoms would repeat in the universe. This means that there is another Earth and another you out there somewhere in the universe right now.



Other universes

If cosmic inflation really happened – the super rapid expansion of our universe in its earliest moments – then it may have happened more than once, giving rise to neighbouring universes. According to Albanian-American cosmologist and theoretical physicist Laura Mersini-Houghton at the University of North Carolina, our nearest universe must be more than 1,000-times further than what we understand to be our cosmic horizon.



An event horizon

It is possible that what we see as our universe is the remnant of a black hole forming in another universe. One of the leading proponents of this idea is theoretical physicist Nikodem Poplawski. If he's right then just like the surface of the Earth, our universe has no edge.



There could be nothing

There is no current reason to suspect that the universe ends with our cosmic horizon, just as we know that the Earth doesn't end just because the rest of the planet is hidden from view by the curvature of the Earth. However, the universe could just stop.

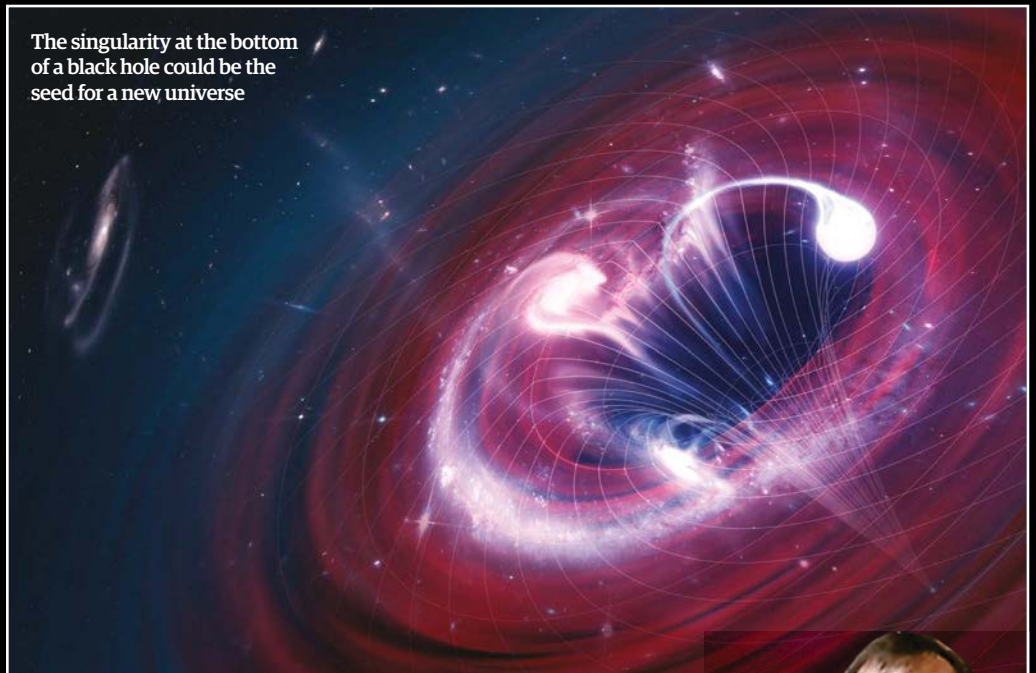
in the vastness of space. Imagine you had six dice and you rolled them a million times. There are only 46,656 different ways those six dice can be rolled, and so in your million rolls it is very likely that you'll roll one, two, three, four, five and six in that order quite a few times. Just as there are a limited number of ways you can arrange six dice, there are also a limited number of ways you can arrange atoms in the universe. In an infinite universe you're effectively rolling the dice an infinite number of times. Just as the one, two, three, four, five and six pattern is likely to crop up multiple times in a million dice rolls, the exact way the atoms in your body are configured is guaranteed to repeat in an infinite universe. So there is a copy of you on a copy of the Earth, reading a copy of this article. In fact, in an infinite universe there are an infinite number of copies of you. However, they are almost certainly located beyond our visible horizon and so you'll never encounter your doppelganger.

This is one version of the multiverse idea. Effectively, you go far enough away in our universe that the cosmos begins to repeat itself and you get multiple copies of the same thing. But there is another version of the multiverse idea, and according to one of its leading proponents, it could tell us more about the edge of our universe. Laura Mersini-Houghton is a theoretical physicist at the University of North Carolina at Chapel Hill. Not only does she believe other universes exist, she also thinks she's found evidence of a neighbouring universe interfering with our own.

It all comes down to the Cosmic Microwave Background (CMB) - the afterglow of the Big Bang, which spawned our universe 13.8 billion years ago. It is a temperature map of the background of empty space showing how the leftover energy from the Big Bang is still slightly warming the universe. The map contains small deviations from the background temperature - tiny hot and cold spots. Except one of the cold spots isn't so tiny. "It covers about ten degrees in the sky," says Mersini-Houghton. The rest of the hot and cold spots are no bigger than a degree. So where did it come from?

According to the leading idea about what happened around the time of the Big Bang, space underwent a stupendous surge in growth in an insanely small period of time. In the first trillionth of a trillionth of a second, the universe grew from something much smaller than an atom

The singularity at the bottom of a black hole could be the seed for a new universe



"Just as the TARDIS door is a door to a spacecraft, a black hole is a spherical door to a new universe"

Nikodem Poplawski, University of New Haven



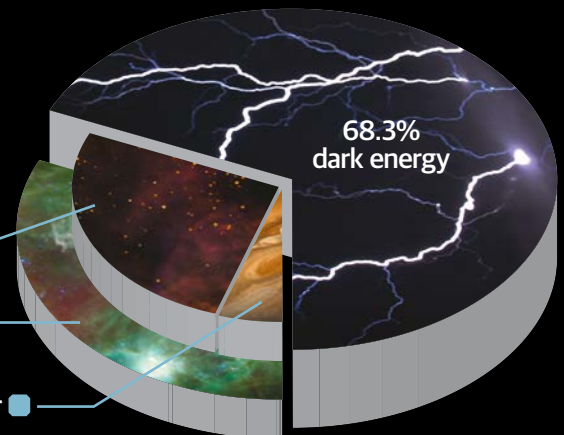
The makeup of the universe

Because the modern universe is dominated by dark energy our cosmic horizon is limited

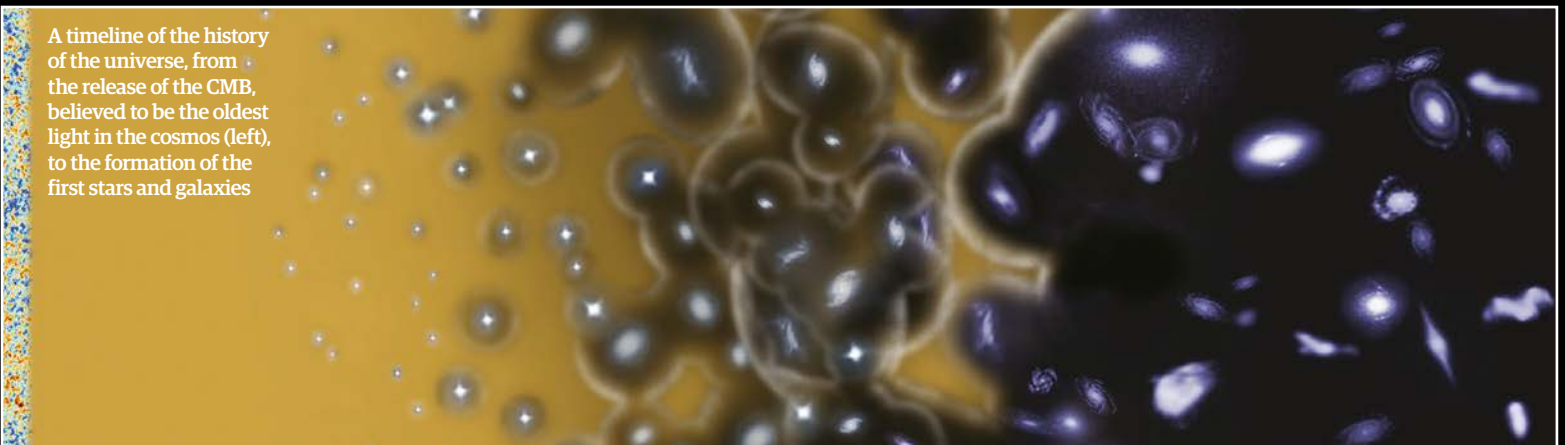
26.8% dark matter

31.7% all matter

4.9% normal matter



A timeline of the history of the universe, from the release of the CMB, believed to be the oldest light in the cosmos (left), to the formation of the first stars and galaxies



to about the size of a marble. It then continued to expand into the universe we see today but at a more sedate, albeit still rapid pace. This initial period of "expansion on steroids" is known as cosmic inflation. According to inflationary theory, the small temperature variations in the CMB are the result of tiny quantum fluctuations during the pre-inflation phase, which were frozen into the universe when it ballooned. As these quantum fluctuations were random and approximately equal in size, so should the hot and cold spots they caused. That's why the presence of one particularly large cold spot has cosmologists scratching their heads. "It's a very significant breaking of the expected uniformity of the CMB," says Mersini-Houghton.

Her explanation is radical, and is by no means accepted by all cosmologists, but it may help us answer the question of where our universe ends. According to one version of inflationary theory, the process didn't just happen once. "Many other universes were created, which are similar to ours," she says. Before each of these universes inflated they would have shared a quantum link between them. "We traced forward that quantum link to see what it would look like at present," she says. The outcome of her calculations was the prediction of a cold spot in the CMB. Crucially, Mersini-Houghton and her team made this prediction public before the cold spot was identified beyond reasonable doubt. Not all cosmologists are convinced, however. "The overall consensus [within the cosmological community] is that the current data doesn't support it," Pontzen says. "It's one of those cases where an extraordinary claim requires extraordinary evidence." Nevertheless, Mersini-Houghton has been able to suggest where the edge of our universe might be if she is right. Her answer? "It is at least 1,000-times further from us than the edge of our cosmic horizon," she says.

She isn't the only one pushing the boundaries of our cosmological thinking and suggesting a potentially revolutionary interpretation of the universe in which we live. Nikodem Poplawski at the University of New Haven, Connecticut, is another physicist challenging our perceived wisdom. "According to general relativity the Big Bang started with a singularity," Poplawski says. A singularity is an infinitely small, infinitely heavy point. This point would have grown to the size of a marble during inflation and then carried on expanding. But the birth of our universe isn't the only place you encounter singularities. "The matter falling into a black hole also ends up at a singularity," explains Poplawski. Black holes are gravitational monsters from which nothing can escape if drawn in. He wondered whether that final singularity in a black hole might actually provide an initial singularity for a new universe.

The trouble with singularities is that an infinitely small, infinitely dense point makes no physical sense. How can something have no size, or be infinitely heavy? So Poplawski hit upon a mechanism by which the matter falling into a black hole gets very close to forming a singularity - an incredibly small, incredibly dense point - but "bounces" before it gets infinitely small and dense. But where does it bounce? Material can't bounce out

The size of the universe

The observable cosmos is not the whole story when astronomers consider how big the universe really is

The Cosmic Microwave Background (CMB) is the furthest that astronomers are able to see from the Earth. This ancient light was released when the universe was approximately 380,000 years old, and has been travelling across the cosmos ever since. The furthest galaxies we can see are almost as far away as the CMB - some 13.8 billion light years away. At least that is

where they were when the light originally set off. While their light has been making its way to the Earth, the universe has carried that part of space ever further from us. That point is now around 45 billion light years away, in effect making the observable universe around 90 billion light years across.

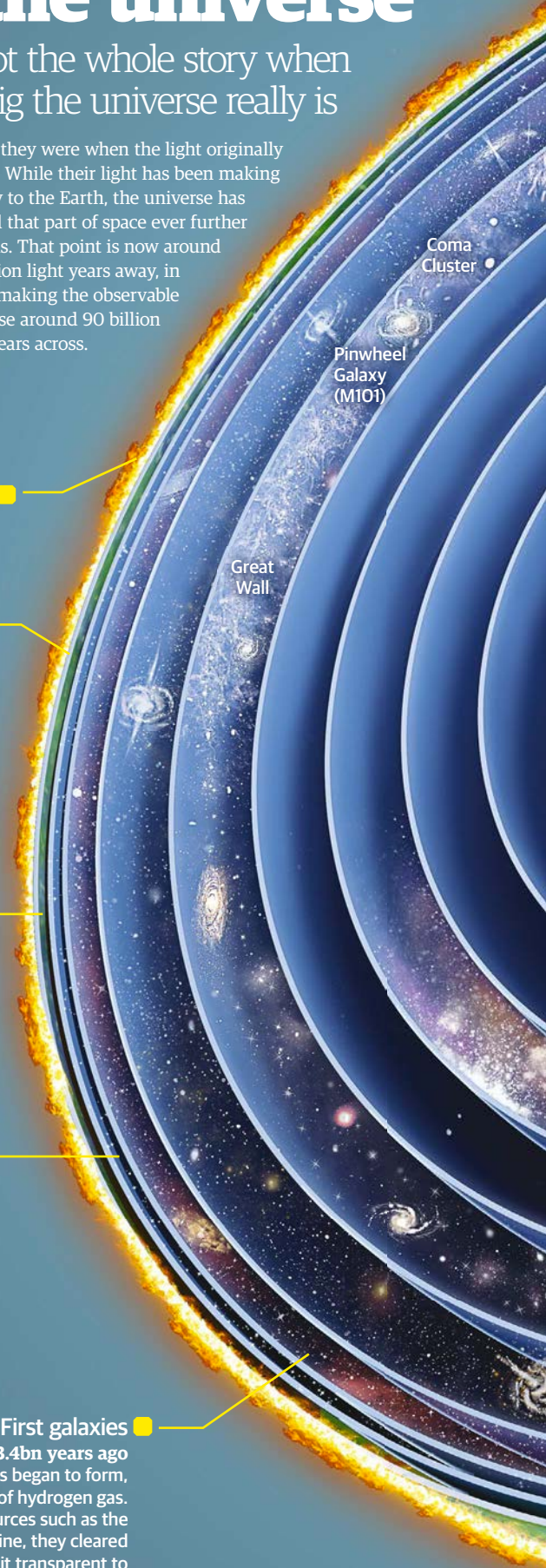
Big Bang ■
Time: 13.8 billion years ago

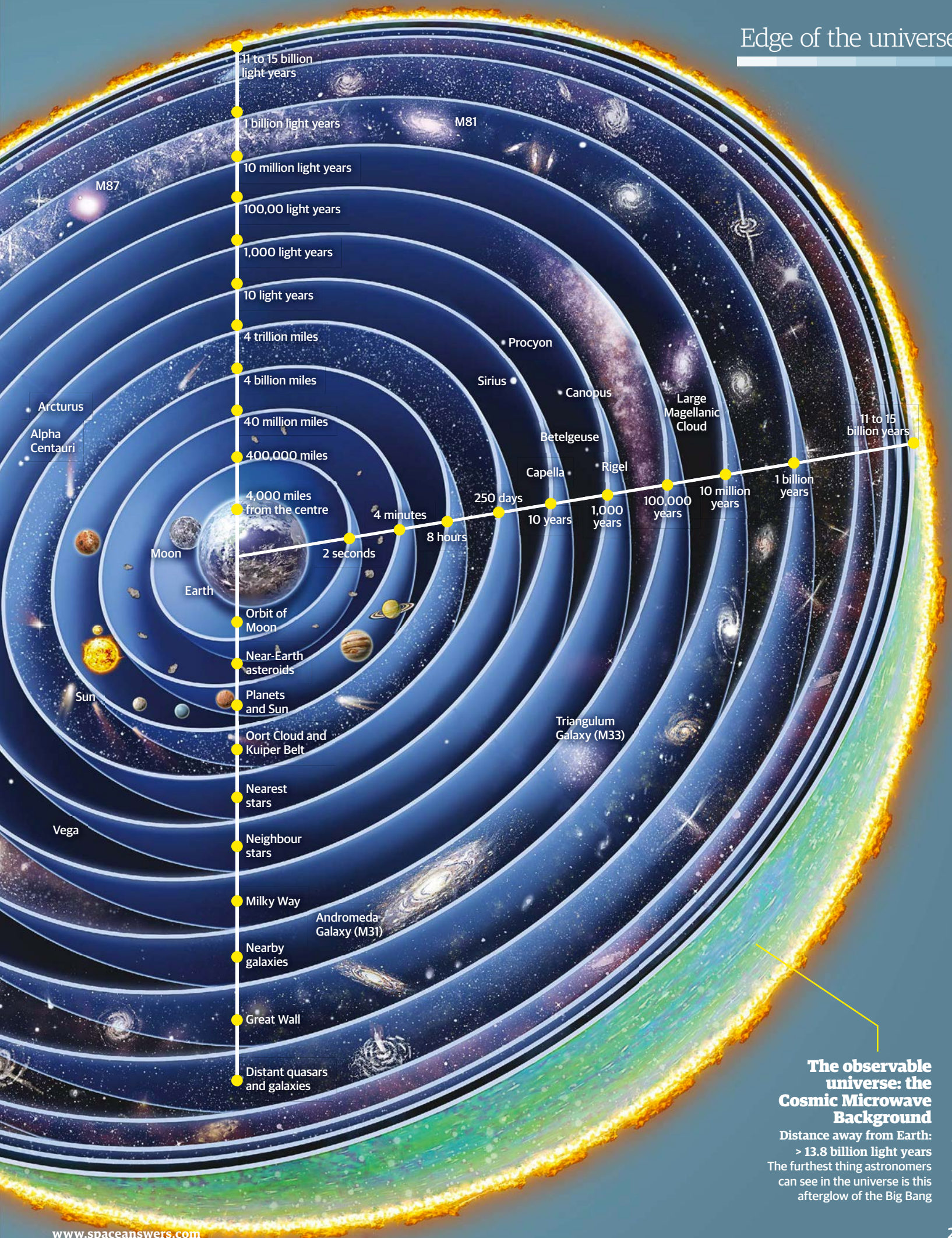
Radiation era ■
Time: 13.8-13.79bn years ago
The radiation era began some two or three minutes to 300,000 years after the Big Bang in a process known as nucleosynthesis. At this stage helium nuclei were formed out of protons and neutrons.

Dark ages ■
Time: 13.79-13.5bn years ago
At this point in the universe's history, the cosmos was opaque and foggy. It's thought that the Dark Ages lasted between 150 million to 800 million years after the Big Bang.

First stars ■
Time: 13.5bn years ago
Fluctuations in the density of the universe meant that the very first stars were able to form. These stars were likely to be quite massive, luminous and produced the first heavy elements that later formed planetary systems like our own.

First galaxies ■
Time: 13.4bn years ago
When the first galaxies began to form, the universe was full of hydrogen gas. However, as powerful sources such as the early stars began to shine, they cleared away this mist, making it transparent to ultraviolet light.





The observable universe: the Cosmic Microwave Background

Distance away from Earth:
 > 13.8 billion light years
 The furthest thing astronomers can see in the universe is this afterglow of the Big Bang

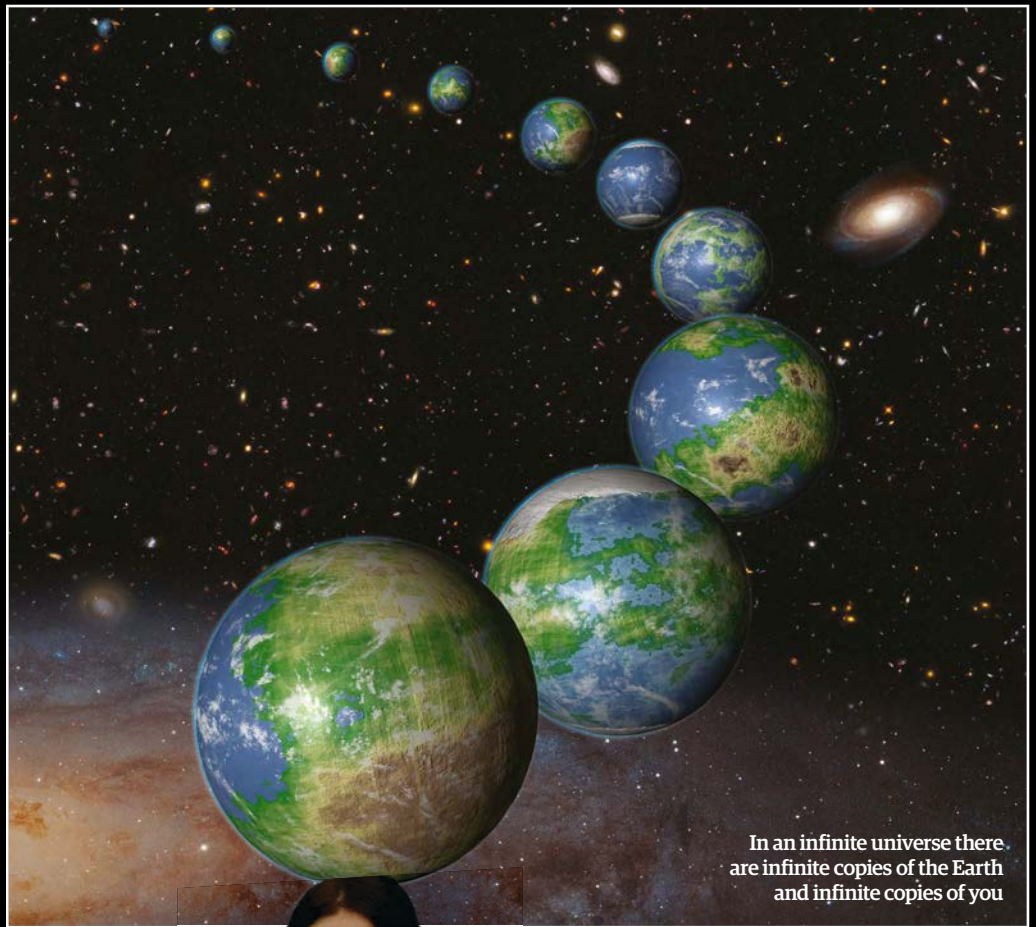
© Nicholas Forder

Edge of the universe

of the black hole because by definition nothing can escape from its clutches. "It has to go somewhere," he says. "After the bounce it explodes and creates new space - a new universe." When explaining his idea to his students he uses an analogy based on the famous science-fiction series *Doctor Who*. "When you enter the TARDIS you realise you're in a space larger than a police box," he says. "Just as the TARDIS door is a door to a spacecraft, so a black hole is a spherical door to a new universe."

So, if Poplawski is right, our universe was created by a black hole in another universe. What does that mean for the edge of our universe? "It wouldn't have one," he says. "It would be like the surface of a sphere." The Earth's surface, for example, has no edge. If you were to walk out of your house and travel in a straight line (albeit across the oceans too) you would end up back where you started. So, according to Poplawski's idea, if you travelled far enough away from the Earth you would end up looping right the way back round and returning home. No edge, no boundary.

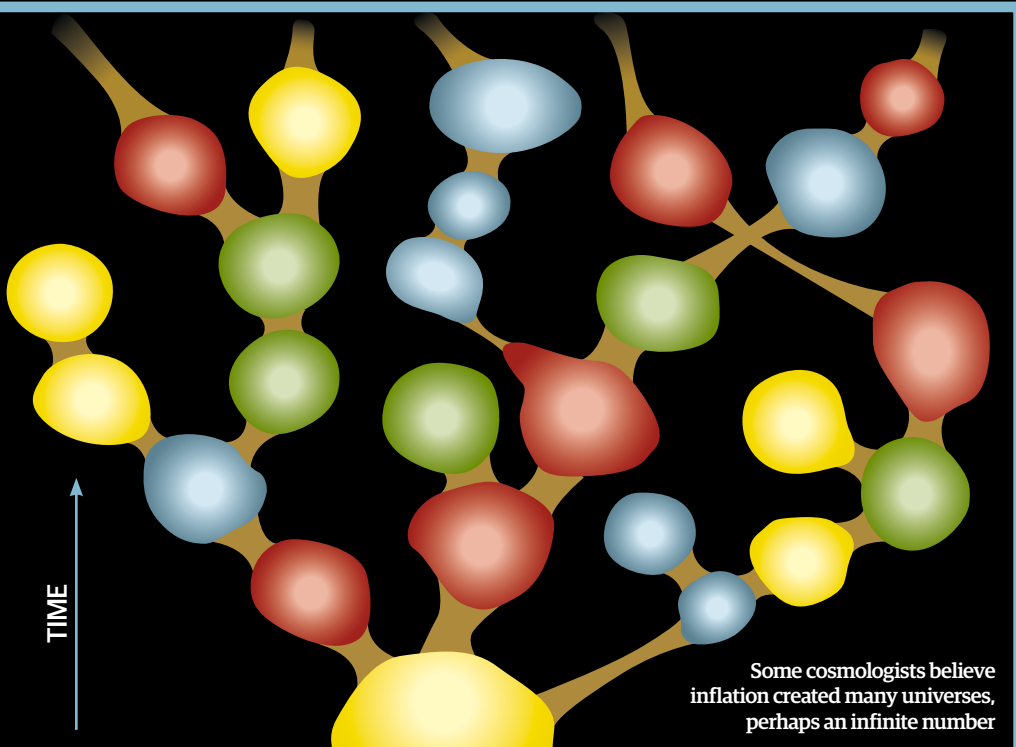
For now it is hard to know which of these pictures is the right one. It could be that the universe ends somewhere beyond our cosmic horizon. Or it could go on forever meaning there are definitely copies of you out there in space. Equally, we could be nested inside one great multiverse, or the calamitous result of a black hole forming in another cosmos. Only further investigation, more observations and a higher volume of astronomical data will be able to tell us more. What is certain though, is that there is more to this universe than meets the eye.



In an infinite universe there are infinite copies of the Earth and infinite copies of you

"Many other universes were created, which are similar to ours"

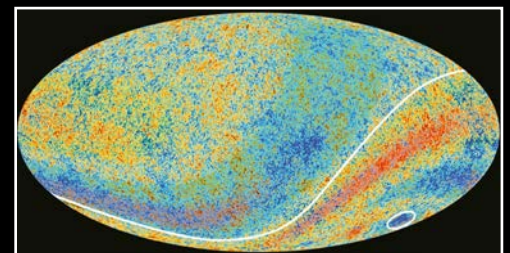
Laura Mersini-Houghton, University of North Carolina



Some cosmologists believe inflation created many universes, perhaps an infinite number



This orbital outpost has provided our best map of the Cosmic Microwave Background



One cold spot in the Cosmic Microwave Background is ten times the size of the other cold spots

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MARS ROVERS

In an unlikely collaboration, the Royal College of Art has been helping NASA envisage cutting-edge Martian buggies with a revolutionary twist

Planetary rovers have a special place in both science and the popular imagination, with roving robots like Curiosity dramatically expanding the range of science we can do on other planets, and human carrying rovers - which combine spaceflight with cars - will be vital to exploration and colonisation. But despite the charisma of these machines, only a handful have ever been made: four Martian mobile robots and three examples of the Apollo Lunar Roving Vehicle (LRV) Moon buggy. However, there have been many studies into future rovers for the Moon and Mars; generally, they have focused on a more substantial pressurised vehicle to support long trips, rather than the LRV's skeletal structure.

NASA's major programme is the Space Exploration Vehicle (SEV), a pressurised multi-purpose module that could support two crewmembers for up to two weeks. It is intended to be used for both ground rovers and in-space vehicles; in its ground rover

"The teams had to provide a complete concept of operations from Earth launch to Mars deployment"

Mission Terra Form

Alicja Pytlewska, Peter Krige, Jeehoon Shin, Teeravit Hanharutaiwan

Runabout
Terra Form's rover is a relatively small transporter for accessing the installed greenhouses, but it still provides a pressurised environment and docking.

Walking greenhouse
Team Terra Form has a walking rover carrying their greenhouse. Once in position the legs could dig the greenhouse into a protective hole.

Mars Space Capsule

Chris Pinches, Kevin Bickham, Nevin De Paravicini, Kyungeun Ko

Individual bi-wheel rovers
Four separate rovers consist of cylinders with a wheel at each end. These provide individual space and transport, but could come together to act as wheels for the whole greenhouse.

Central greenhouse
The Mars Space Capsule team's design has a large central greenhouse that would be established autonomously before the crew are launched.

form the standard module would be integrated with a 12-wheel, electrically powered chassis, 4.5 metres (14.8 feet) long and four metres (13.1 feet) wide. SEV is likely to be the basis of NASA's next planetary transport, whether that is on the Moon or Mars first; but in an effort to look further ahead, and seek out new ideas that might not occur to the organisation, NASA recently collaborated with the UK's Royal College of Art (RCA) on a rover concept challenge.

Dual masters students from the RCA's Innovative Design Engineering and Vehicle Design courses worked together in teams to develop Mars rover concepts; featuring living and greenhouse spaces, with a holistic consideration of physical and psychological comfort during long trips. The teams also had to minimise mass, volume and energy consumption, and provide a complete concept of operations from Earth launch to Mars deployment. Interestingly, the project has produced six rover

concepts all very different from the NASA SEV. Team Borea's concept features large expandable rear wheels that could stretch out into an array of feet for difficult terrain, and the team hope to extract energy for the vehicle from the Martian winds; including rather optimistically supporting one end of the body with rotors, while being blown along.

The Mars Space Capsule team have proposed creating a central greenhouse module that would be sent to Mars and established autonomously; then a crew with four separate rovers would follow. Each rover is individually a cylinder with a wheel at each end; this side-by-side bi-wheel arrangement would provide the rover with proportionately very large wheels for good obstacle capability. However, if the bumps get too big the whole cabin could spin round within the wheels! These four rovers, which would provide personal space and transport for the crew, could then come together to dock with, and

potentially transport, the whole greenhouse, acting as a wheel at each corner.

Mission Terra Form's concept also features a two-part system, but the autonomous greenhouse module is a walking rover with six legs; as well as providing transport, these would be used to dig the greenhouse into the soil. This would form a botanical base for a new settlement, serviced by four-wheel rovers that would allow colonists direct access to the greenhouses. The Ulysse team focused on the environment inside the rover; a large eight-wheel rover with glazing to open out the space and avoid claustrophobia. The communal space is rapidly reconfigurable for different phases of the day, but critically they have created permanent personal spaces for the crew, for individual rest and reflection. All of these concepts demonstrate how there are many ways to go roving on Mars. Now it's up to NASA to take a concept and turn it into a reality.

Ulysse

Audrey Gaulard, Matt Batchelor, Larry Finnegan, Paul Nichols, Adam Setter, Henry Cloke

Extensive glazing
The Ulysse rover focuses on the crew environment; it is a large pressurised rover with extensive windows to provide a feeling of space and connection with the outside.

Flexible space
The communal spaces will be conveniently reconfigurable, but the crew will also get their own permanent personal space for individual privacy.

Borea

Mimi Zou, Luc Fusaro, Chulhun Park

Combined wheel-turbines
To collect energy from the environment, other wheels on Borea incorporate aerodynamic turbines that could function as wind generators when stationary.

Expanding all terrain wheels
Mars rovers may have to cover hugely varied terrain. Team Borea's design features wheels that can stretch out into an array of feet.



NEXT Giant Leap

13 ways to conquer space

How we'll solve the greatest challenges of exploring the cosmos and send humans further than ever before

Written by Luis Villazon

It might seem as if crewed space exploration stalled after the Apollo Moon landings for purely political reasons, but the truth is that the real hurdles were put there by the laws of physics. Mars is more than 140-times further away from Earth than the Moon is at its closest, and uncrewed probes typically take eight months to get there. Former NASA administrator Charles Bolden said that he wanted new propulsion systems that will cut the journey time to Mars in half. But even a fast mission to Mars will need to arrive ready for a 26-month stay on a barren, hostile world, while the crew wait for the planets to reach opposition again for the return trip. That's a two-year survival challenge of breathtaking proportions - and just to visit the most welcoming planet in the Solar System!

After a 40-year hiatus, government space agencies and private companies are now focusing on crewed space exploration, but Mars is not the final goal - it's just the next step. Humanity will eventually walk on even more distant planets and moons, perhaps even those in other solar systems. To pull that off, though, we'll need to develop an incredible array of new technologies, from propulsion and guidance, to food preparation and habitat construction. Let's take a look at the progress so far.

Landing on another world - without crashing!

SOLVED BY:

Hypersonic retropropulsion

Landing on Mars is nothing like landing on the Moon or Earth. For a direct insertion trajectory, a spacecraft will be travelling at approximately 21,000 kilometres (13,000 miles) per hour when it arrives. Mars has only one per cent of the atmospheric density of Earth but at that speed, this is still enough to heat the outside of the spacecraft to 1,600 degrees Celsius (2,912 degrees Fahrenheit) - which is around the melting point of titanium! By the time it has reached 12 kilometres (7.5 miles) above the surface, the spacecraft is still travelling at 1,450 kilometres (900 miles) per hour. NASA's Curiosity rover used a parachute to slow down to 595 kilometres (370 miles) per hour and this technique might be useful on Saturn's moon Titan, or Venus - both of which have dense atmospheres. But the much heavier weight of a crewed landing craft makes parachutes impractical on Mars.

The solution is rocket engines that can be reliably ignited in the face of an air-stream rushing towards you at hypersonic speeds. SpaceX has been developing exactly this technology for the reusable first stage of the Falcon 9. The data it has gathered over the last few years will be vital when its Dragon 2 capsule lifts off on its first uncrewed test mission to Mars, scheduled for 2018.

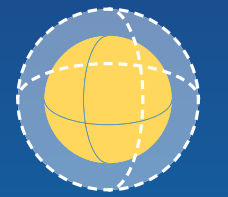
1 Vacuum is cleaner

On an airless planet or moon, landing is easy, provided you bring enough fuel.



2 Atmospheric friction

With an atmosphere, you need to slow down gradually first to avoid burning up from compression heating.



3 Multiple passes

Dipping into the atmosphere to lower your orbit a little each time is the safest way.



4 High-speed re-entry

Alternatively, save time by using an inflatable heat shield and braking hard in a single pass.



5 Propulsive landing

Parachutes aren't enough on worlds with thin atmospheres like Mars. You need powerful landing motors.



Space is too big to explore

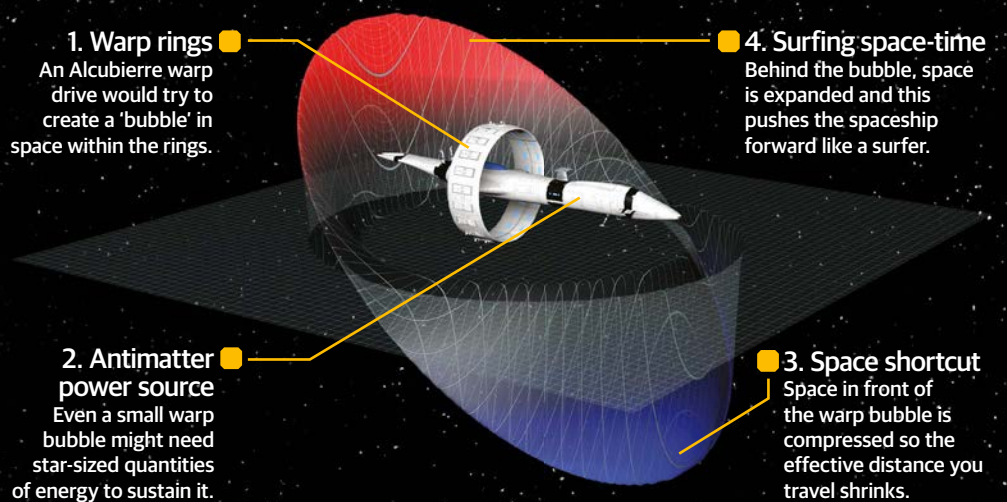
SOLVED BY: *Hyperspace technology*

Once we cast our sights beyond the confines of our Solar System, the distances involved get truly daunting. If we were able to accelerate a small probe to 0.5 per cent the speed of light, it would still take 860 years to reach the nearest star. And even this would require more hydrogen fuel than we could feasibly get our hands on. The Breakthrough Starshot proposal, backed by Stephen Hawking and Mark Zuckerberg, could cut this down to 20 years using a laser array aimed at a huge light sail but this would only work for a probe weighing just a few grams.

To send larger spacecraft in any realistic timescale, we will need some kind of warp

drive technology. Theoretical physicist Miguel Alcubierre found one possible solution to Einstein's space-time equations that would distort space itself, to cover huge distances quickly without locally exceeding the speed of light.

The problem is that the equations for this space-time geometry appear to require exotic matter with negative energy densities - in other words, antigravity. Nothing in our current understanding of physics gives us any hope that such exotic matter exists. So in the end we may simply be substituting one impossible problem for another. Even Alcubierre himself doesn't believe that a warp drive is practical.



Springs simulate heavy weights in microgravity and are much cheaper to carry into space

Wasting away of bone and muscle

SOLVED BY: *Tumbling dumbbells*

Astronauts in microgravity lose up to two per cent of their bone mass each month. The heart also gets used to working less hard to pump blood around and when the crew return to Earth, they can black out if they stand up too quickly. Balance and spatial orientation are affected as well. After an 18-month journey to Mars, astronauts could find that they arrive at their weakest, just when the critical tasks of establishing a surface base require them to be strong.

On the ISS, two hours per day are spent exercising on treadmills or pulling against elastic to simulate weight lifting. But it's still not enough and astronauts always return to Earth weaker than when they left. Spinning the craft provides a way to use centrifugal force as a substitute for gravity but it needs a lot of space. If the craft rotates once every 15 seconds, the diameter of the wheel would need to be 112 metres (367 feet) to simulate Earth gravity - larger than the entire ISS, including solar panels! One way to save space would be to use a dumbbell design with the crew compartment at one end of a long truss, and the engines at the other. The entire ship could tumble end over end during the coast phase of the journey.

Avoiding space junk

SOLVED BY: *Decommissioning old boosters and trash collection*

Space is no longer a pristine wilderness. Since 1957 we have been dumping an assortment of junk in low-Earth orbit. The largest objects are actually the upper stages of old rockets and residual fuel left in their tanks can get heated by the Sun and cause them to explode. NASA now requires rockets to vent their unused propellant to prevent this but the wreckages of hundreds of old upper stages still hurtle around the Earth. These objects are at least easy to track from the ground but there are much smaller pieces of debris too. Tiny grains from the exhaust of a solid rocket motor, or flecks of paint dislodged by the harsh sunlight, are invisible until

they strike, but if they hit a satellite travelling in a different orbit, their relative velocities can pack the punch of a sniper rifle.

If space debris isn't cleaned up it can enter a runaway cascade called Kessler Syndrome, where the debris causes satellites to break up into thousands of pieces, which strike other satellites. At least three satellites have been destroyed by collisions with space debris since 1996. Spacecraft can protect themselves from small debris using multilayered 'Whipple' shielding, such as the panels that protect the ISS, but the larger items may need to be hunted down and de-orbited, one by one.

WHERE IS IT?

95% is below 2,000km (1,243mi) altitude

Highest concentration at 800-850km (500-530mi)

HOW BIG IS IT?

170 million particles are 1cm or smaller (0.4in) - smaller than a pea



500,000 objects are 1-10cm (0.4-4in) - up to the size of an apple



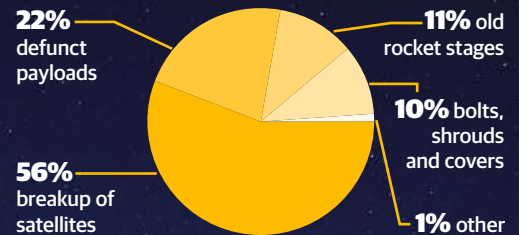
20,000 objects are 10cm (4in) or above - larger than an orange

WHERE DOES IT GO?

50% of the debris from a collision re-enters the atmosphere within ten years

10% may still be in orbit after 50 years

WHERE DOES IT COME FROM?



SOME ODD SPACE JUNK



A glove
Lost by astronaut Ed White during the first American spacewalk



A camera
Dropped by Michael Collins from Gemini 10



Garbage bags
From Soviet Mir space station



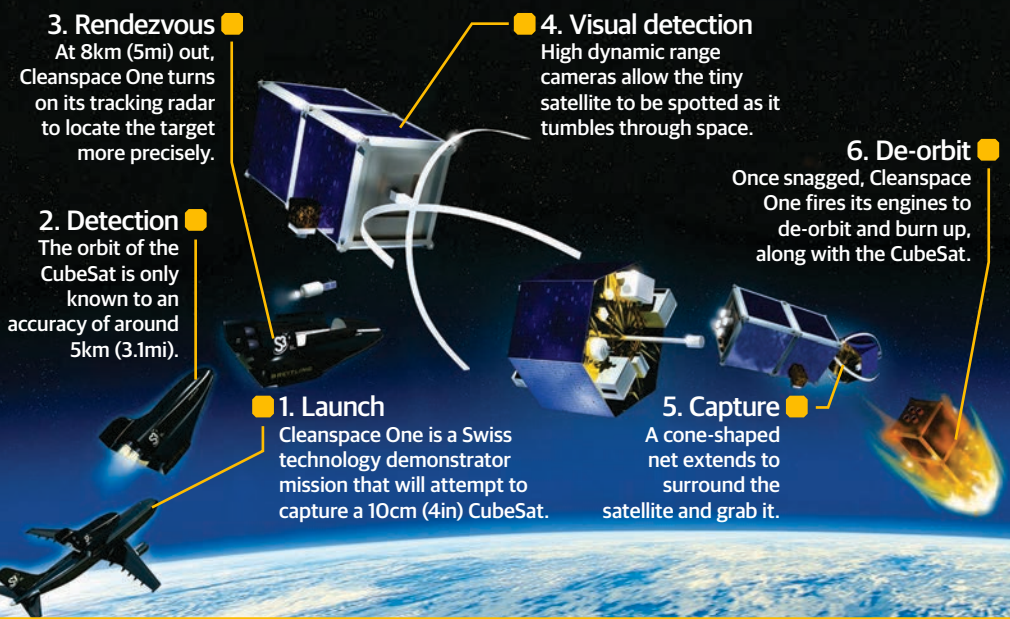
A toothbrush
Lost through the hatch of Apollo 15



\$100,000 tool bag
Misaid by astronaut Heidemarie Stefanyshyn-Piper



Pliers
Lost during STS-120 Space Shuttle mission



HOW MUCH IS THERE?



Total mass: 5,500 tons, which is equivalent to 350 double decker buses

HOW HARD DOES IT HIT?

6km/s (21,600km/h)

- or 3.7mi/s (13,422mph)

CHANCE OF IMPACT

Between **800-900km** (500-560mi) altitude, satellites have a **1%** chance of being hit by debris within their **5-10 year** life span

NOTABLE COLLISIONS:

1996

French Cerise surveillance satellite is hit by debris from an old Ariane rocket. This is the first known accidental debris collision.

2007

China fires a missile into a head-on collision with the Fengyun-1C weather satellite as an anti-satellite weapons test.

2009

Iridium communications satellite collides with a defunct Russian satellite. 2,000 pieces of traceable debris created.



Humans can't colonise worlds alone

SOLVED BY: *An army of robots*

Setting up a colony is hard work and it doesn't make sense to use humans for all the jobs. Just the fact that robots don't need to eat, drink or breathe on the long journey to another planet is an argument for using them, and they will likely precede us to any planet we travel to. A lot of the initial work at an extraterrestrial colony will be digging - a difficult job for humans to do safely. NASA has designed the Regolith Advanced Surface Systems Operations Robot (RASSOR) to cope with digging on lower gravity worlds. It uses counter-rotating scoops at the front and back, so that it doesn't need to rely on its own weight to press into the ground. Once the basic colony is established, robots will still be essential to harvest water from the subsoil, for drinking and splitting into oxygen and hydrogen.



Avoiding space madness

SOLVED BY: *Using virtual reality*

Cramped conditions, lack of leisure time, monotonous food and the dangers of outer space make for a stressful workplace. NASA has conducted several long-duration habitation studies simulating a Mars base at the HI-SEAS facility in Hawaii, and the main conclusion so far is that crew conflict is inevitable. Regardless of how carefully astronauts are screened, arguments and meltdowns are certain. Several studies have found that the mid-point of the mission has the most potential for a flare up, as that's when morale is lowest and the crew has the least to do.

Until deep space hibernation technology is perfected, one way to avoid space madness is through virtual reality (VR). The Digital Arts Leadership and Innovation (DALI) is researching ways to use VR to reduce homesickness and give astronauts an escape from the stressful environment of the spacecraft.

Having enough food and water

SOLVED BY: *Energy bars*

Feeding astronauts on deep space missions isn't as simple as bringing seeds and plant pots. Even on Mars, the challenges are enormous. If you use natural light for photosynthesis, the Martian farmers will need to don spacesuits while tending the crops due to radiation. And while Mars' atmosphere is mostly carbon dioxide, the pressure is much too low to grow outside of a sealed dome. The sheer space that agriculture requires means that self-sustaining food production wouldn't be more efficient than hauling all the food from Earth, until a Mars colony has

hundreds of people living on it. On long journeys to the outer planets, the problem is even worse. Water can be recycled indefinitely from a sealed spacecraft but food can't. Even if it was possible to use exhaled CO₂ and human waste to grow nutritious algae, no crew could tolerate eating it for long. Small-scale hydroponic greenhouses could grow salad greens as a morale-boosting treat but potatoes and soybeans take much longer to grow. For Orion missions, NASA is developing nutritious food bars that will provide a meals-worth of calories in a single space-saving slab.



NASA food scientists have cooked up a series of 700-to-900-calorie bars to replace an entire meal



We only know of one Earth

SOLVED BY: *Making a new home*

When settlers arrived in America, they found a fertile land with fresh water and wildlife. Space colonisation isn't going to be like that. Mars is cold and doesn't have enough of an atmosphere, while Venus is hot and has too much. The moons of Jupiter and Saturn have lethal radiation, Pluto is too cold, and Mercury is too hot. Beyond our Solar System, things are even worse. The nearest extrasolar planet is Proxima Centauri b. This is technically an 'Earth-like' world but it's a relative term; it's tucked into a tiny orbit against a dim red dwarf star and receives two per cent of the visible light we get on Earth but 400 times more X-ray radiation. The temperature is 20 degrees Celsius (68 degrees Fahrenheit) colder than Earth and the gravity could be three-times higher.

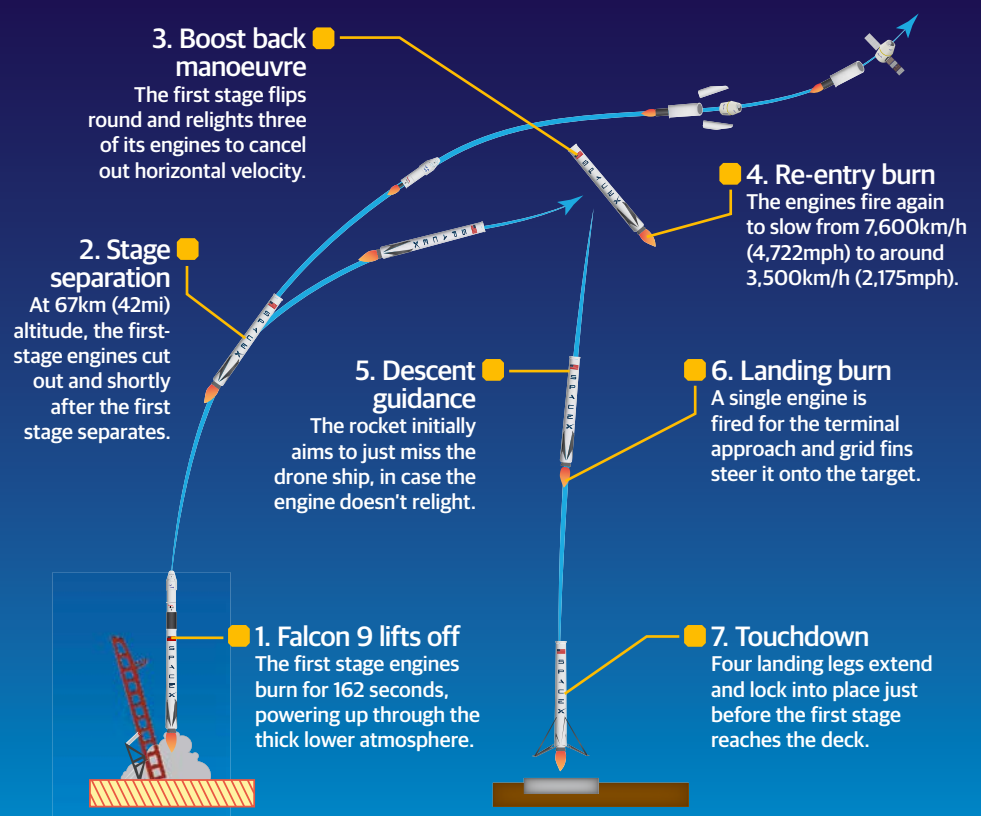
If we're ever going to visit worlds like this, we'll need to be good at building protective, self-sustaining habitats. It's best to start small with a permanent base on our Moon, then Mars. The experience we gain in off-world engineering will be invaluable.

Escaping gravity without massive costs

SOLVED BY: *Reusable rockets*

Blasting straight up against the pull of gravity is not that hard. To lift a one-ton payload into space requires 100 gigajoules of energy, and just the Space Shuttle's main engines can deliver around a third of this every second! But anything you lift straight up will inevitably come straight down. To get into orbit, you need to add enough sideways velocity to reach 7.8 kilometres (4.8 miles) per second, and that requires much more energy. Because you have to lift the rocket as well as the payload, these energy requirements can quickly escalate unless you jettison some of the weight on the way up.

But discarding spent stages makes each rocket a single-use device and that's expensive. The Space Shuttle tried to improve on this but refurbishing the solid rocket boosters and the orbiter was costly at \$450 million (£359 million) per launch - twice the cost of a Saturn V. This all changed in December 2015 when SpaceX flew the first stage of a Falcon 9 back to Cape Canaveral and landed it near the launch site. Since then, they have landed another six rockets and SpaceX president, Gwynne Shotwell, has said that reusing these first stages could bring costs down to just \$5 million (£3.9 million) per launch.



Getting faster spacecraft

SOLVED BY: *Nuclear, plasma and chemical propulsion*

To get to more distant places in space, you need to travel faster. This isn't just so that you get there sooner, it's so that you get there at all. Without enough velocity pumped into your orbit, the trajectory of your spaceship won't curve out far enough to intersect with your target. Tsiolkovsky's rocket equation states that the amount of velocity you can add to a spacecraft is determined by the amount of fuel it carries and the exhaust velocity or 'specific impulse' produced by the fuel when it is burned. Current rockets, such as the Falcon 9 or Soyuz, burn a mixture of high-grade kerosene and liquid oxygen. This is cheaper and easier to handle but it only has an exhaust velocity of three kilometres (1.9 miles) per second.

With a rocket that is 95 per cent fuel, you can accelerate to three times the exhaust velocity, or nine kilometres (5.6 miles) per second. The New Horizons mission to Pluto needed more than 16 kilometres (ten miles) per second, so it had to weigh less than 0.15 per cent of the Atlas V that launched it. The most efficient theoretical rocket fuel is liquid hydrogen, used on some rockets, but even this isn't enough to allow us to send realistic-sized payloads to the outer planets and beyond. The only way we will manage that is with more exotic engine designs.

VASIMR

Average speed: 180,000km/h

Type of rocket: Plasma
Destination: The inner planets
Height: 1m (3.2ft)

The Variable Specific Impulse Magnetoplasma Rocket, or VASIMR, engine uses radio waves to heat and ionise the argon propellant, and a magnetic field to accelerate this through the exhaust nozzle. It has almost no



RS-25 (NASA), Raptor (SpaceX)

Average speed: 13,000km/h

Type of rocket: Chemical
Destination: Mars

Height: 4.2m (13.8ft)

By using super-chilled liquid methane instead of kerosene as fuel, and very high combustion chamber pressures, the next generation of chemical rockets will produce three times more thrust at 18 per cent higher efficiency.



NERVA

Average speed: 25,500km/h

Type of rocket: Nuclear thermal

Destination: Mars and Jupiter

Height: 43.7m (143.4ft)

A NERVA rocket uses the heat from a nuclear reactor to boil and expand a stream of liquid hydrogen so that it is forced out as high-speed exhaust – a design that is twice as efficient as chemical rockets. NASA has test-fired prototype NERVAs for several hours at a time.



© Adrian Mann



Having enough resources for the mission

SOLVED BY: *Living off the land*

Surviving on the surface requires a base. As well as living space, the explorers will need greenhouses, labs and hangers to protect rovers and equipment. It isn't feasible to land enough construction material to assemble all this, so we'll need to use the materials we find. NASA is working with Clouds AO to develop 'inflatable' base modules filled with ice mined from the Martian soil, as water absorbs radiation while still allowing visible light through. The water is extracted from the soil by heating it, and the liquid water is pumped into the double-walled cavity, where it refreezes. But ESA has taken this further and developed a robotic 3D printer that can assemble entire buildings from Moon regolith, creating its own cement and driving around the walls as they grow.

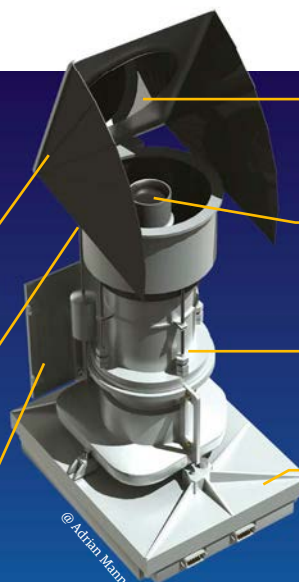
Navigating space

SOLVED BY: *Tracking the constellations*

Sunshade
A folding shade allows star tracking even at angles close to the direction of the Sun.

Periscope tilt motor
Rotates the mirror to adjust the view, while another motor provides sideways panning.

Radiator
Sheds heat to keep electronics cool and reduce thermal distortions in the lenses.



Periscope mirror
Allows the DPS unit to scan the sky without rotating the entire spacecraft.

Telescope optics
A wide-field lens identifies star constellations and a high-magnification gives precision.

Compact design
The entire unit is just 32cm (12.6in) long when stowed and weighs less than 5kg (11lb).

Camera electronics
Image processing extracts navigation information from the relative positions of the stars.

GPS navigation has limited effectiveness for spacecraft in low-Earth orbit, but it doesn't work at all once you travel further afield. NASA is considering plans to implement a similar system for navigation on Mars, but it isn't feasible to put a network of 24 satellites around every planet in the Solar System. As we travel further, the need for cheap, accurate, standardised navigation

systems becomes more critical. NASA's JPL has developed the Deep-space Positioning System (DPS). This can scan the sky and identify constellations, without the craft needing to use its own altitude control thrusters to rotate. As well as the visible spectrum, the DPS can also scan X-ray wavelengths for increased star coverage and has its own radio antenna to calculate the relative position to Earth.

Space radiation

SOLVED BY: *Plastic and magnets*

Mission planners might be able to shrug off the additional cancer risk from a one-week round-trip to the Moon, or a six-month stay on the International Space Station, but journeys further afield are a different matter. The radiation trapped in Jupiter's magnetic field is so harsh that it can destroy uncrewed probes. The Juno craft has all the shielding of a flying tank and uses enlarged components in its integrated circuits to give it better fault tolerance from high-energy particle impacts.

For deep-space voyages, crewed flights can protect themselves from solar radiation by pointing the heavy engine towards the Sun, or using the stored drinking water as a shield. But Galactic

Cosmic Radiation (GCR) comes from all directions at once. These particles are also travelling so fast that when they strike the aluminium walls of the spacecraft they create a cascade of secondary radiation, which is actually even more dangerous to the astronauts inside. Some plastics can interact with GCR particles to produce less harmful secondary radiation and human waste from the life support system could also be used as shielding.

But the spacecraft will probably also need to generate its own protective magnetic field. The SR2S project is working with CERN to investigate the feasibility of using superconducting magnets to generate a radiation shield.

Where space radiation comes from

Exploding stars, magnetic fields and only vacuum to stand in their way!



The Earth

The magnetic field traps solar wind in the Van Allen belts from 1,000-60,000km (621-37,300mi). Satellites crossing the belt receive 25,000mSv radiation per year.



The Sun's rays

The Sun emits light at all wavelengths but Earth's atmosphere screens out most of the shorter wavelengths. In space, ultraviolet radiation is 100-times stronger.



Galactic Cosmic Radiation

The gas clouds left after a supernova have magnetic fields that accelerate heavy ions to almost the speed of light, which continually bombard our Solar System.



Coronal Mass Ejections

Solar flares can cause the Sun to blast a few billion tons of its upper atmosphere into space. If this is pointing at Earth, we receive a huge gust of solar wind.



Solar wind

The Sun blasts a thin plasma of electrons, protons and alpha particles at 400km/s (250mi/s). Orbits close to Earth are protected by its magnetic field.

- Dose in millisieverts (mSv)
- 3.6** = Average annual radiation dose on Earth (all sources)
 - 7** = Chest CT scan
 - 50** = Annual limit for radiation workers
 - 11.4** = Apollo 14, nine-day mission to the Moon
 - 160** = Six months on ISS
 - 1,200** = Three-year round trip mission to Mars
 - >1 million** = One-year in orbit within Jupiter's radiation belt

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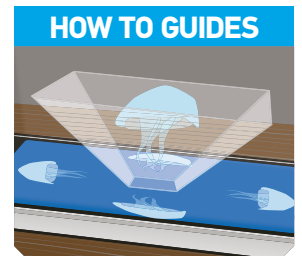
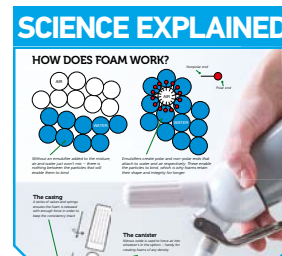


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ASTEROID ATTACK

Is Earth ready if a space rock strikes?

A new 'doomsday plan' is due to be accelerated by the US government in the event of a potential asteroid impact

It's one of the most popular disasters in movies, such as *Armageddon* and *Deep Impact*, but unfortunately for us, the threat of an asteroid hitting our planet and wiping out civilisations is extremely real. Even worse, the recent release of an official document by the White House reveals that we're extremely under-prepared should a space rock decide to strike. It's enough of a wake-up call for the US government to put together a plan, which will see the country collaborate with other nations.

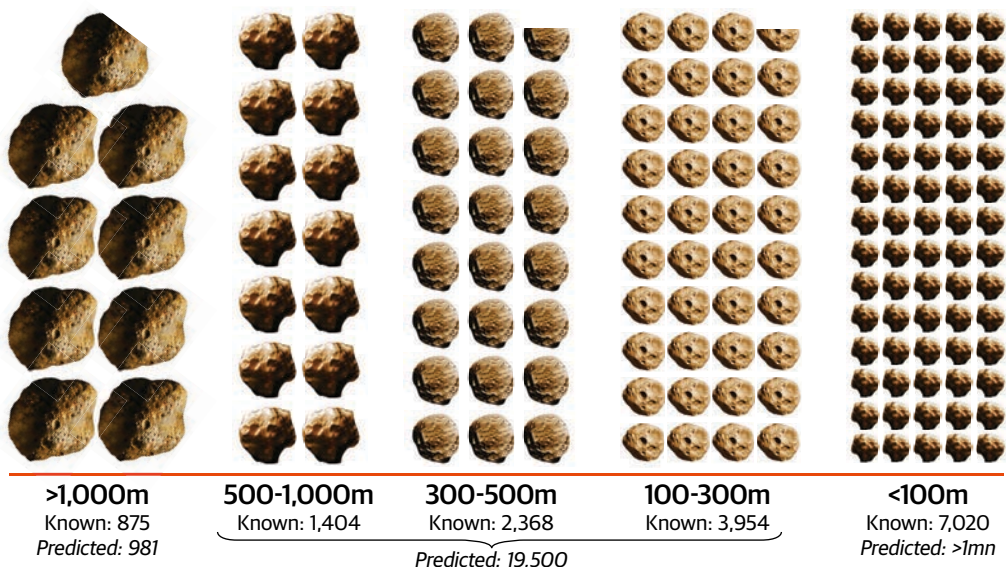
Entitled the *National Near-Earth Object Preparedness Strategy*, the action plan aims to improve the nation's preparedness to address the hazard of Near-Earth Object (NEO) impacts by enhancing our current capabilities to detect a potential threat, as well as developing methods to deflect and disrupt the asteroids, comets and meteorites heading our way. In fact, if one of these hazardous objects were to zoom towards our planet in the future, it certainly wouldn't be the first time. Back in 2013, a 17-metre (56-foot) meteor exploded

in the atmosphere over Chelyabinsk, Russia, injuring more than 1,000 people with no warning. However, while dangerous asteroids and comets rarely hit Earth, the threat always looms. "They are the extinction-level events, things like dinosaur killers, they're 50 to 60 million years apart, essentially," says Dr Joseph Nuth, a researcher at NASA's Goddard Space Flight Centre in Maryland. "You could say we're due, but it's a random course at that point."

NASA currently uses the watchful telescopic eyes of NEOWISE, a spacecraft that relentlessly searches for potential threats as part of the Asteroid Watch programme, but is working on a series of missions including an asteroid redirect mission, which will see a robotic spacecraft visit a space rock to make an orbiting base for astronauts. The new strategy, however, states that the US intends to collaborate with other countries. "Although currently a global leader in detecting and tracking NEOs, the United States will depend (in part) on international cooperation and coordination," the report states.

How many space rocks have skimmed our planet?

With some the size of houses and others as big as football pitches, an alarming number of asteroids have wandered astronomically close to our planet



According to a report compiled by the White House, Earth is under-prepared for an asteroid impact

The White House's major goals for asteroid avoidance

- ✓ Enhance the detection of Near-Earth Objects as well as technologies for tracking and characterising them
- ✓ Develop methods for the deflection and disruption of Near-Earth Objects
- ✓ Improve modelling, predictions and information integration
- ✓ Develop emergency procedures for Near-Earth Object impact scenarios
- ✓ Leverage and support international cooperation
- ✓ Establish coordination and communications protocols and thresholds for taking action



MERCURY IS SHRINKING

The smallest planet in our Solar System is getting even smaller

Written by Giles Sparrow

Mercury is shrinking

Mercury can be easy to overlook - as not only the smallest rocky planet but also the closest to the Sun, it is hard to spot on its fleeting visits to our twilight skies, and never appears in full darkness like brilliant Venus or blood-red Mars. At first glance it also lacks the complexity of its planetary neighbours - while Venus has a dense, hostile atmosphere and volcanic landscape and Mars has its tantalising similarities to Earth, Mercury is an airless ball of grey rock that most closely resembles our Moon.

Over the past decade, however, our view of the innermost planet has been transformed by NASA's MESSENGER space probe. The first spacecraft to orbit Mercury has revealed that this mysterious world has a complex history of its own, with a distant volcanic past, a core much larger (relative to its overall size) than that of any other planet, and an active magnetic field. Perhaps most intriguing of all, however, is the evidence that this tiny planet has shrunk considerably since it formed.

"Mercury is the least understood of our Solar System's four terrestrial worlds, because until relatively recently it was extremely hard to image or to visit," Dr Paul Byrne of North Carolina State University tells **All About Space**. "It's deep in the Sun's gravity well and we simply didn't know how to get a spacecraft into orbit around it until 1985, when Chen-wan Yen at JPL came up with the orbital trajectory you needed to follow." As a result of these challenges, before this decade most of our information about Mercury came from a single NASA space probe that made three flybys of the planet in 1974 and 1975. Mariner 10 flew in a solar orbit that intercepted Mercury's, but the geometry of the two orbits meant that its encounters only revealed a little less than one half of the planet's surface.

Despite the secrets of reaching a Mercury orbit being known from 1985, actually sending a spacecraft on the complex trajectory still presented considerable challenges, and it was not until 1998 that NASA seriously began to consider launching such a mission. Early proposals eventually evolved into the ambitious MESSENGER (MErcury Surface, Space ENvironment, Geochemistry and Ranging) mission, which launched from Cape Canaveral in 2004 and entered orbit around the scorching planet in March 2011 after a tortuous flight involving one flyby of Earth, two of Venus and three of Mercury itself.

"I had the good fortune to be a member of the MESSENGER science team, so I've been with the mission pretty much from its early days," recalls Dr Tom Watters of the Smithsonian Institution's Center for Earth and Planetary Studies. "We were in a happy position as the second spacecraft to visit Mercury and the first to actually orbit the planet, so in terms of pure discovery we were seeing parts of the planet that had never been seen before by a spacecraft."

Some of the most distinctive features on Mercury, known from the initial Mariner 10 flybys, were the elongated cliffs that weave their way across the cratered landscape. In places, they cut craters in two, creating either a sharp height difference between one side of the crater and the other, or in some cases riding up across and completely burying part of the crater. "It was pretty obvious from Mariner 10 images that these fault scarps were widespread, and that suggested at least the parts of the planet that we

Mercury is shrinking

could see had contracted," continues Watters. "It's like what happens to an apple when its core starts to dry out and shrink, and the skin starts to wrinkle and adjust to it. But we couldn't be sure the effect was global. Then, when MESSENGER made its first flyby of the unimaged hemisphere in 2008, one of the first things that popped out was another of these very large scarps, which we now call Beagle Rupes. So it was really after that we could confirm that we were looking at a *global* contraction of the planet."

So why exactly do these winding cliffs point to a shrinking planet? Byrne takes up the story. "These kinds of scarps are really not so uncommon, and you see them on Earth in tectonic settings [where they are caused by our planet's ceaselessly shifting continental plates pushing up against each other and overlapping]. But the question was why are these features so common on Mercury, which doesn't have separate plates? In order to answer this, you need a global shrinking process. If the volume of the planet is shrinking, then its surface area has to reduce as well to accommodate that shrinkage. So what we're seeing in the lobate scarps is blocks that are being thrust up over their surroundings as the

crust shrinks." Predictions that Mercury has shrunk over time go back to before the Mariner mission, and in fact, shrinking is an inevitable part of any rocky planet's history.

The collision processes that form rocky planets inevitably leave them with a molten interior - conditions in which heavy metals like iron and nickel sink into the centre to form a hot core, while lighter elements such as silica and oxygen remain closer to the surface, combining in silicate minerals to form a rocky mantle. Surrounded by the cold of interplanetary space, such hot planets must inevitably cool down over time, and just as a sticking door shrinks and closes more easily in cold weather, so the cooling of planetary interiors leads inevitably to a reduction in the amount of space they take up. The other rocky planets have hidden much of

the evidence of their own shrinkage through other geological activity, but on Mercury it remains for all to see, written in the starkly beautiful cliffs of the lobate scarps.

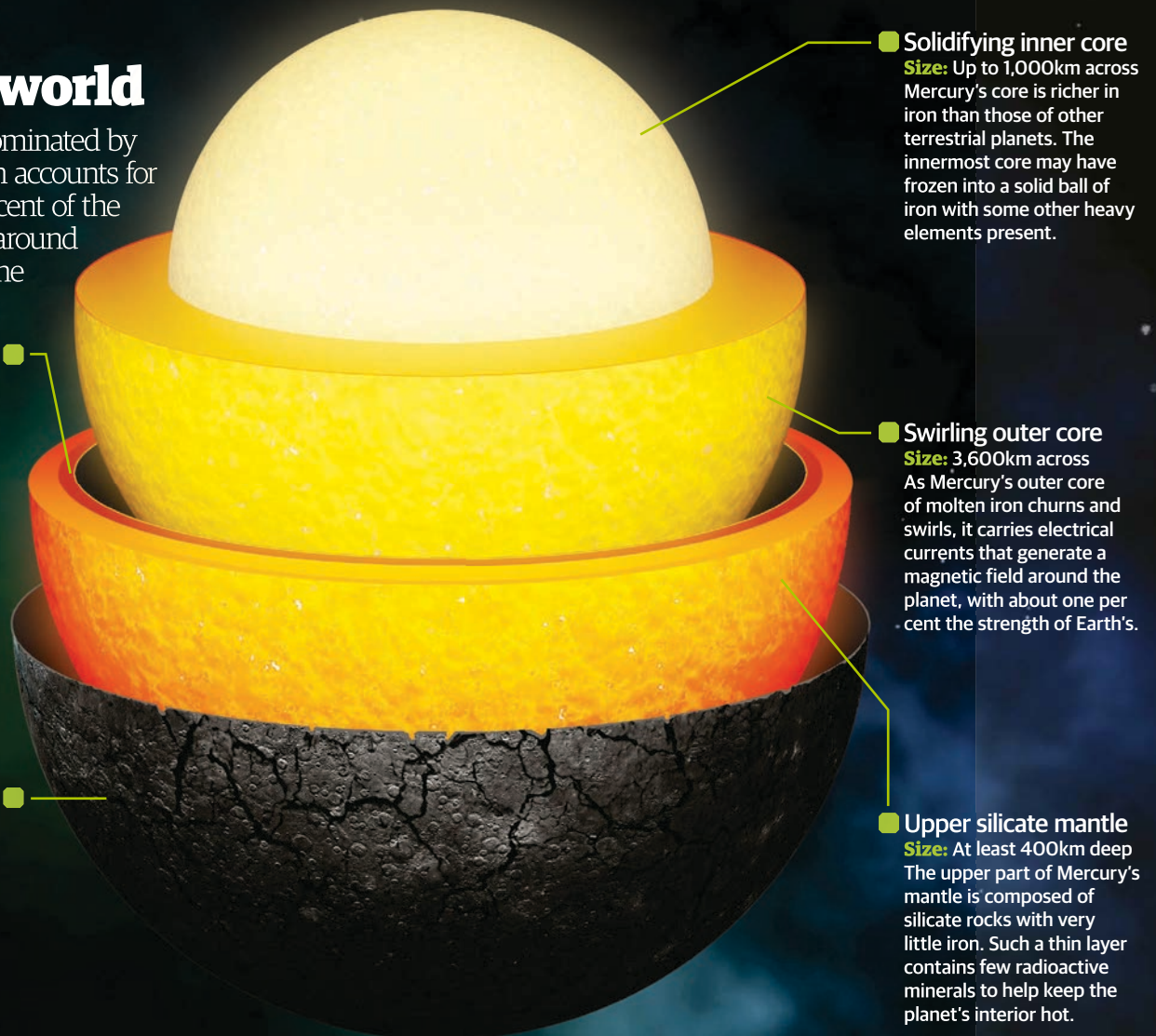
Adding to this is another mysterious aspect of Mercury - its giant metallic core. Discovered from density measurements taken during the Mariner 10 flybys, Mercury's core is about 3,600 kilometres (2,237 miles) across, surrounded by a thin mantle and crust that together are only about 420 kilometres (261 miles) deep. "Mercury's outsized core and thin mantle mean that it radiated heat more quickly," says Byrne. "So its contraction started sooner and lasted longer. The crux of the issue is just how much the planet has contracted." Armed with MESSENGER data that includes a photographic



"Mercury is the least understood of our Solar System's four terrestrial worlds" **Dr Paul Byrne, North Carolina State University**

Inside a shrinking world

Mercury's interior is dominated by a huge iron core, which accounts for approximately 80 per cent of the planet's diameter and around 55 per cent of its volume



© Tobias Roetsch

survey of the whole planet from different angles and laser altimetry data to reveal the height of different structures, that might sound like a relatively simple question to answer, at least in principle. But it's here that Byrne and Watters come to starkly different conclusions, putting them on either side of a debate that's been running since the 1970s.

"Post-Mariner 10 models of Mercury's interior predicted a radius change of between five and ten kilometres (three and six miles) through its history," recalls Byrne. "But early observations suggested an *actual* change of between one and two kilometres (0.6 and 1.2 miles). So the basic contraction models were saying one thing and the geologists something else, and until we could resolve that gulf, we couldn't really use the model to make other predictions about Mercury's history."

"We're all pretty much in agreement that the principal influence on the contraction is a slow cooling of the interior," says Watters. "But I think part of the emerging debate is the question of how slow that interior cooled. You're going to expect more contraction from a faster-cooling interior rather than a slower-cooling one. Along with colleagues, I started

"The cooling of planetary interiors leads inevitably to a reduction in the amount of space they take up"

How Mercury is getting smaller

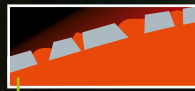
Changes to internal temperature and loss of heat into space have caused the little planet to develop widespread surface faults

Early phase of expansion

Early in its history, Mercury's already-hot interior grew much hotter and swelled in volume, as radioactive minerals in the mantle released energy as they changed their form.

Cooling and contraction

Thanks to its thin mantle, the heating effect of radioactive elements dwindled rapidly and the loss of heat became dominant. As the planet's interior cooled, it began to shrink.



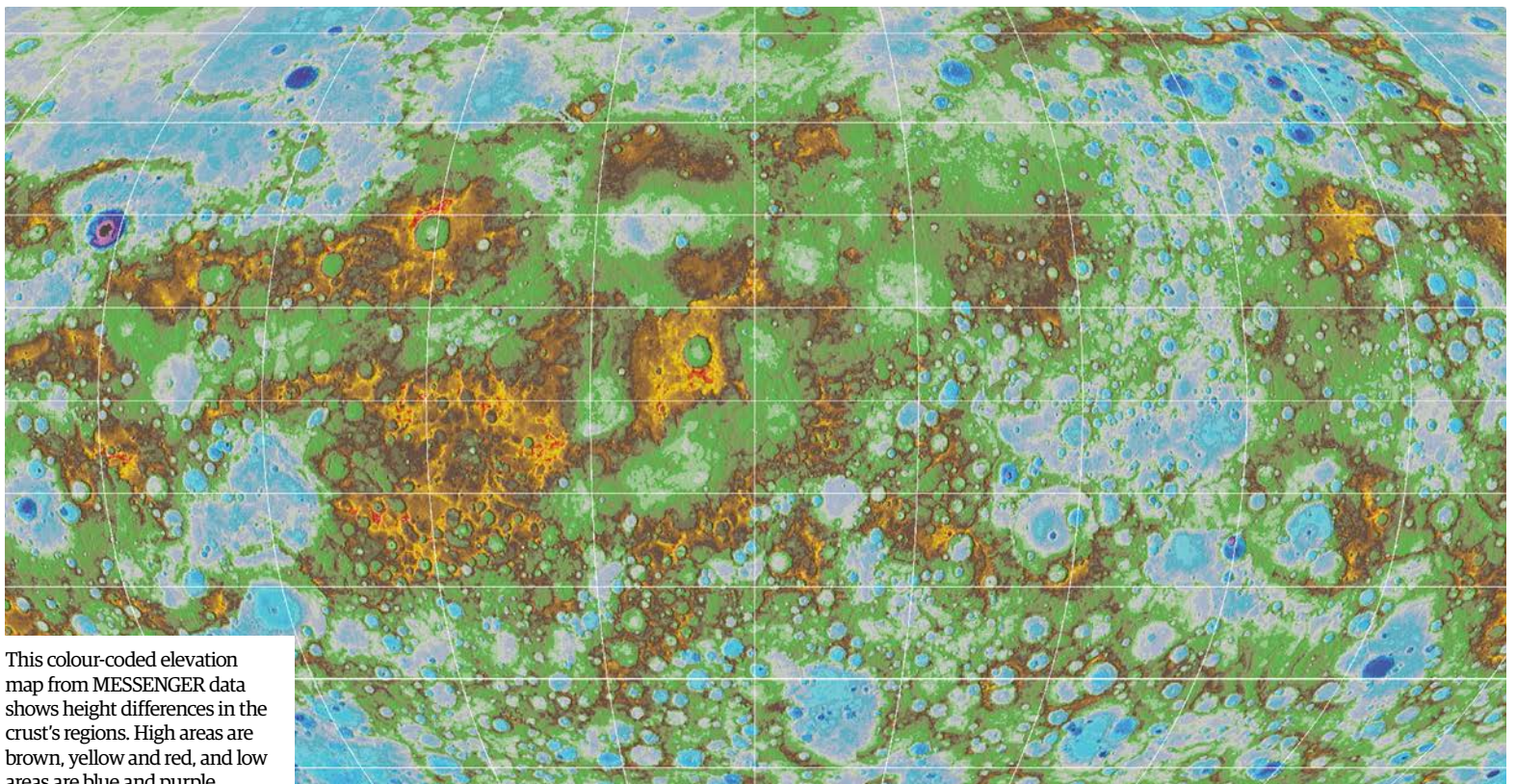
Splitting crust

As the interior expanded, Mercury's crust fractured, allowing volcanic lava to rise up and fill the gaps. These early features were later obscured by heavy asteroid bombardment.



Scarp formation

Shrinking of the interior created stress as the solid crust attempted to contract. Eventually it manifested in thrust faults that pushed certain areas up above others, creating widespread lobate scarps.



This colour-coded elevation map from MESSENGER data shows height differences in the crust's regions. High areas are brown, yellow and red, and low areas are blue and purple

Mercury is shrinking

Other shrinking worlds

Mercury isn't the only large world in the Solar System that's shrunk throughout its history

The Moon

In 2010, Tom Watters and colleagues studying data from the Lunar Reconnaissance Orbiter found small-scale lobate scarps on our Moon.

With a maximum height of about 100m (328ft) and an age of less than a billion years, they suggest that the Moon took longer to cool and shrink than previously thought.



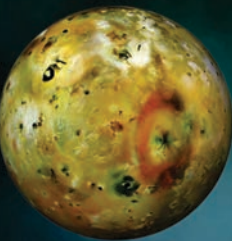
Earth

In theory, Earth might have cooled and contracted a little over its 4.5-billion-year history, but its larger size, smaller core and deeper mantle, rich in heat-generating radioactive materials, mean that it has probably shrunk very little since reaching equilibrium after its formation.



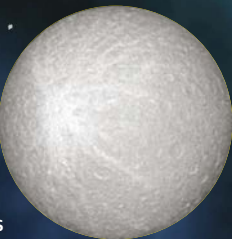
Io

The most volcanic moon in the Solar System, Io is tortured by tidal forces from Jupiter. But the moon is home to towering mountains up to 17km (10.6mi) tall that aren't volcanic. In 2016, researchers suggested the peaks are created by faulting as the crust shrinks and collapses under the weight of volcanic lava.



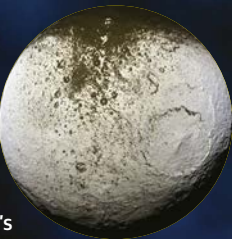
Rhea

This large icy Saturnian moon has a heavily cratered surface - any 'cryovolcanic' flows of ice on its surface came to an end more quickly. Some geologists speculate that the moon's larger size caused it to shrink and grow denser earlier in its history, changing the structure of its interior into a far more solid ice.



Iapetus

Saturn's mysterious moon has a bright and a dark hemisphere, but it's also circled by a mountainous ridge that runs around its equator. One possible explanation for the moon's walnut-like shape is that it once had a pronounced equatorial bulge that later shrank back, except for on the equator itself.



looking again at the Mariner 10 data in the late 1990s. There's a well-established relationship from Earth and other planets between the length of a fault and the amount of displacement that occurs along the fault, and when we applied that, we were pushing it to get to even one kilometre (0.6 miles) of shrinkage."

Watters continues, "Adding data from the early MESSENGER flybys allowed us to make a new calculation that increased the amount of shrinkage slightly, but we were still talking about one kilometre (0.6 miles) or so. Even with full maps of the surface, our estimates still don't put us above two kilometres (1.2 miles) at most."

Byrne and his colleague Christian Klimczak at the University of Georgia began to look at the problem themselves in 2012. "We mostly wanted to understand the distribution of these scarps. But once you've got that information about number and distribution, you can also make an estimate of the radius reduction using some basic assumptions. What we found using two different approaches was that the amount of shrinkage all these structures represented was somewhere between four and seven kilometres (2.5 and 4.3 miles). What's more, you can't just look at the structures on any world simply by adding up the visible scarps and making some geometric assumptions, because there's an amount of deformation anything made of rock will withstand before it starts to form lobate scarps. It's like standing on a table - the table doesn't break or even deform immediately, but you're still applying a stress to it." Byrne continues, "Our colleagues have calculated that

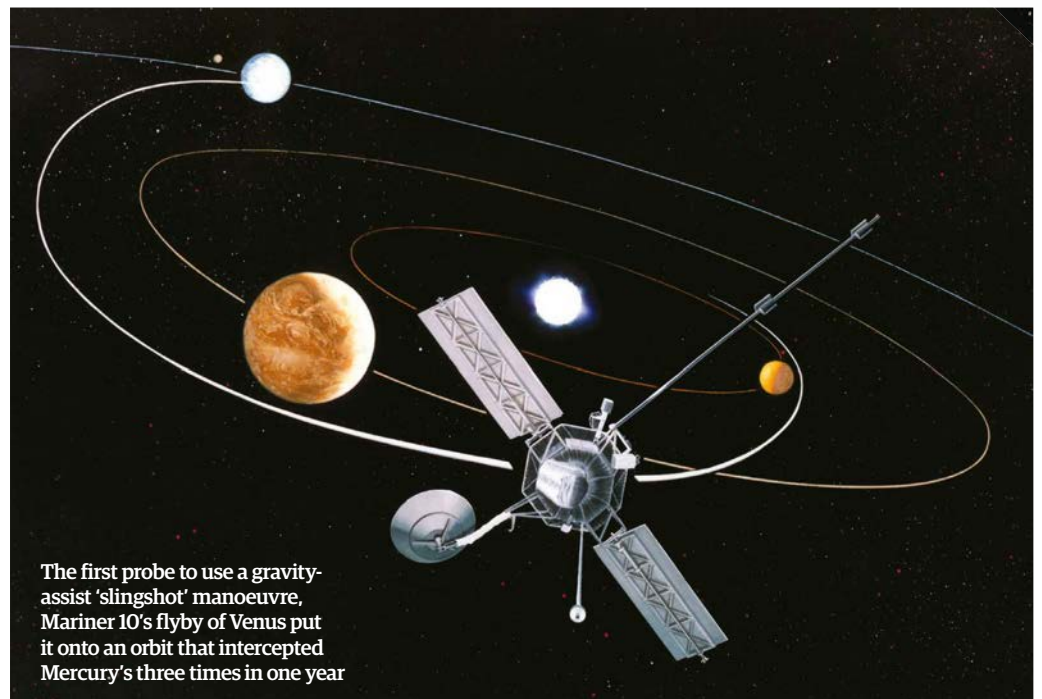
amount of deformation to be between a few hundred metres and perhaps two kilometres (1.2 miles), which suggests that Mercury's radius change has been somewhere between five and nine kilometres (3.1 and 5.6 miles). That's a pretty broad range and there are a lot of estimates involved, but they're educated estimates, and they've ended up with a figure that comes in way higher than those predicted before, and right around what the contraction models suggest."

Watters disagrees with the idea of Mercury's crust absorbing a substantial amount of 'hidden' shrinkage before it started to form scarps - but why such a big difference in the figure the two geologists derive from the *visible* evidence? Watters explains it like this: "In the simplest terms, when I make a tectonic map I assign one master fault to each structure, while Paul [Byrne] will assign multiple faults around a single structure. I'd argue that those are secondary and tertiary features that don't contribute significantly to the total contraction."

Byrne agrees this is at the heart of their differing results: "Tom [Watters] fundamentally doesn't include all the landforms that we include, and as a result his value for the amount of radius change is considerably lower." With both scientists using the same basic principle, it all comes down to the rules they use for including scarps and other deformation features.

So who is right? Byrne's estimates have the advantage of matching the long-standing models of Mercury's thermal contraction, and, he argues, they help explain some of Mercury's other present-day features. "Once you allow more contraction and add

"Before this decade, most of our information about Mercury came from a single NASA space probe that made three flybys of the planet in 1974 and 1975"



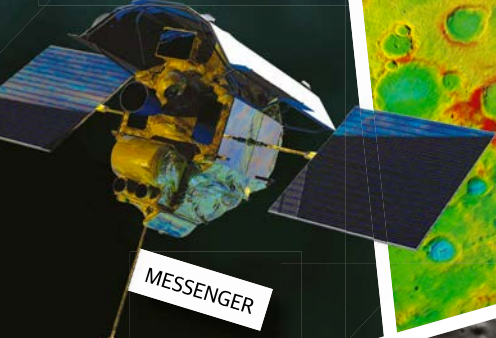
The first probe to use a gravity-assist 'slingshot' manoeuvre, Mariner 10's flyby of Venus put it onto an orbit that intercepted Mercury's three times in one year

Postcards from Mercury

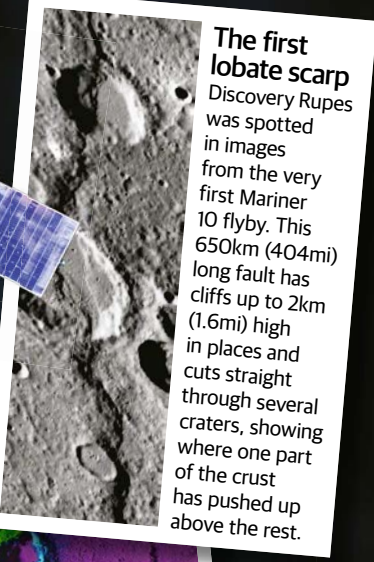
The pint-sized planet is home to some spectacular surface features, including many that point to its history of shrinking



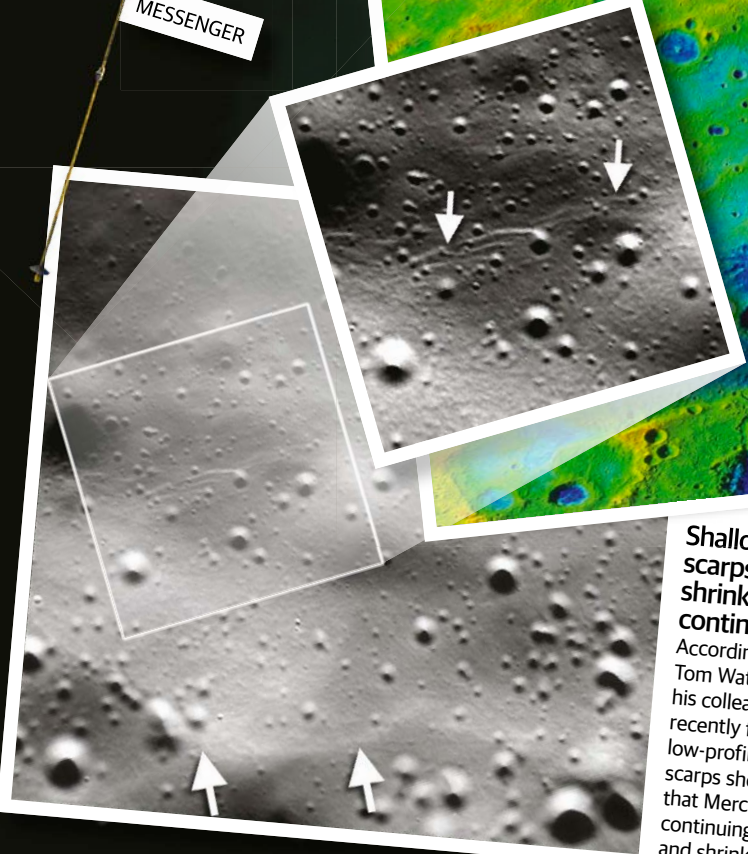
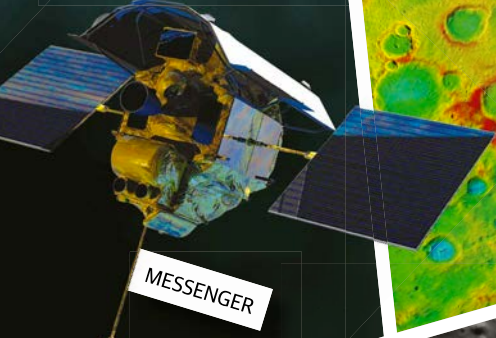
The longest fault of all
Enterprise Rupes, discovered by the MESSENGER science team shortly after the probe's arrival at Mercury, is the longest scarp on the planet - a 1,000km (620mi) fault with a distinct turn halfway along its length, and cliffs up to 3km (1.9mi) tall.



A valley between faults
Identified by Tom Watters and colleagues in 2016, the 'Great Valley' in Mercury's southern hemisphere is a broad plain some 400km (250mi) wide and 1,000km (620mi) long - a depressed area in between two uplifted scarps around 3km (1.9mi) high.



The first lobate scarp
Discovery Rupes was spotted in images from the very first Mariner 10 flyby. This 650km (404mi) long fault has cliffs up to 2km (1.6mi) high in places and cuts straight through several craters, showing where one part of the crust has pushed up above the rest.



Scarp on the hidden side
Beagle Rupes was the first major scarp to be spotted on Mercury's unimagined side during MESSENGER's 2008 flyby. It cuts across a 220 x 120km (137 x 75mi) crater called Sveinsdóttir, with a cliff about 800m (2,625ft) high.

Shallow young scarps show shrinking continues
According to Tom Watters and his colleagues, recently formed low-profile scarps show that Mercury is continuing to cool and shrink today.

Future of Mercury

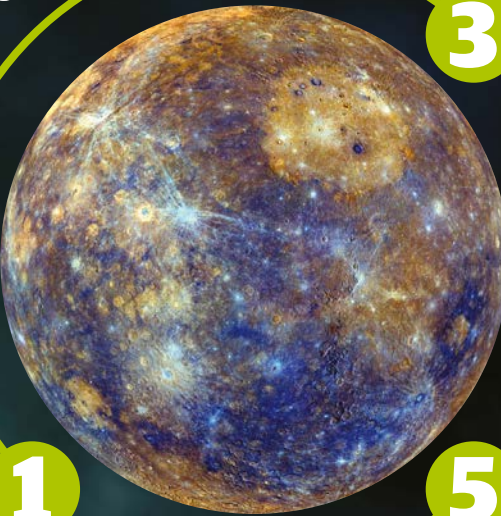
If it's still cooling and shrinking today, then what does the future hold for the tiny planet?

Contraction comes to an end

In a billion or more years from now, the shrinking of the interior finally dwindles to a point where it cannot create enough stress for more faults to form in the crust.

More faulting on the surface

Small-scale faults may continue to form and even grow in size, as the continued cooling and contraction of Mercury's interior places more stress on the crust.



Fresher faults are wiped away

Over hundreds of millions of years, small-scale faults are erased from the surface, obscured by the slow but steady processes of meteorite bombardment.

The core continues to solidify

As the interior continues to cool, the solid inner core of iron grows in size, leaving the molten iron outer core trapped between two solid shells.

The magnetic field shuts down

Finally, the dynamo effect of swirling electric currents in the molten outer core grows too weak and Mercury's magnetic field dies, leaving only traces of fossil magnetism in its rocks.

in new data about the surface composition to your geological models, then you suddenly find a lot of things begin to line up, for instance, explaining the presence of the magnetic field today," says Byrne. "If these new models are more consistent with our observations, then it might suggest that this measurement is more robust than previous ones."

Watters, however, suggests that some of MESSENGER's final discoveries about the planet could undermine those long-standing models of its cooling, and instead chime better with his measurements. "In the last phase of the mission we were able to lower MESSENGER's orbit and we started picking up signs of ancient frozen magnetic fields over the volcanic plains. The assumption had previously been that Mercury's magnetism is a late-stage event, perhaps triggered by freezing-out of a solid inner core, but these volcanic rocks are about 3.7 to 3.9 billion years old," explains Watters. "They show that Mercury has had a long-lived magnetic field for billions of years but that doesn't really work with earlier thermal history models, which predicted fairly rapid cooling of the interior and a large amount of contraction. Instead, we're looking at an interior that's been cooling more slowly to keep the dynamo effect going."

Another intriguing discovery has been very shallow fault scarps - shallow features that can only be a couple of tens of million years old, as otherwise they'd have been eroded away by meteorite impacts. "If you couple that with a long-lived magnetic field indicating slow cooling, that seems to suggest that Mercury is still shrinking today," argues Watters. "So I think that's radically changed the picture and makes it harder to explain the larger contraction figures." Byrne isn't so sure, however: "Tom's small lobate scarps may be a modern-day manifestation of cooling and crust contraction, but there's an interesting question of why, if they're due to compression, those new structures would form instead of continuing to dump the strain into the existing faults."



BepiColombo mission, due to launch in 2018, consists of the European-built Mercury Planet Orbiter (foreground) and Japan's Mercury Magnetospheric Orbiter

"We're looking at an interior that's been cooling more slowly to keep that magnetic dynamo of molten material going" **Dr Tom Watters**



MESSENGER's spectacular mission to Mercury came to an end when it crashed into the planet's surface in April 2015, so this seems like an argument that could run and run. "I think the issue is only really going to be resolved if and when another group revisits the question from scratch and produces their own maps," admits Byrne. "That would be a useful test for both of our maps and our criteria for including landforms."

Fortunately, new data may eventually help resolve the question - if we're willing to wait the best part of a decade. BepiColombo, a joint European and Japanese mission to Mercury, is scheduled for launch

in late 2018 and should arrive in orbit around the tiny planet in December 2025. With a more circular orbit than MESSENGER, the mission should provide better data about Mercury's terrain and magnetism - particularly in the southern hemisphere where the longest and deepest lobate scarps seem to be concentrated. In the meantime, however, there's plenty of data from MESSENGER still to sift through, doubtless more secrets to be revealed, and more debates to be had about this incredible shrinking planet. As Watters puts it, "science would be boring if we were all on the same page and agreeing with each other all of the time!"

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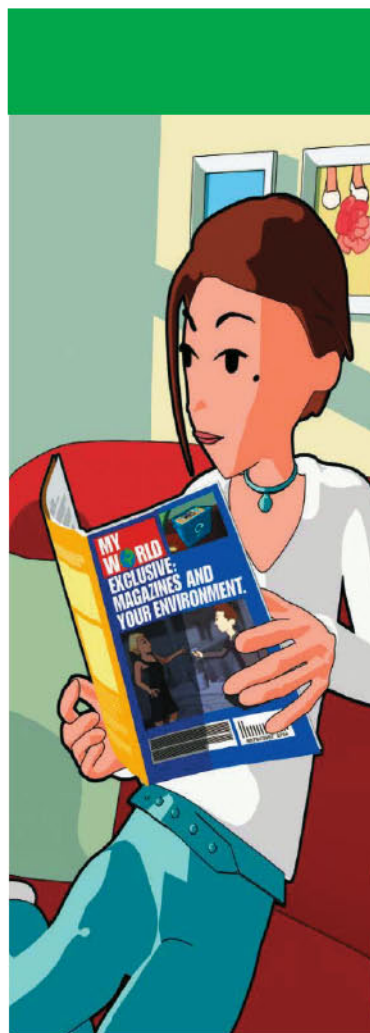
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Cracking the secrets of the *'physics-defying'* INTERSTELLAR EMDRIVE

For years, we've looked for ways to test whether an EmDrive could power a craft without propulsion. Dr Mike McCulloch has a theory that could help

Interviewed by David Crookes



INTERVIEW BIO

Dr Mike McCulloch

Dr Mike McCulloch is a British physicist at Plymouth University. As well as lecturing in Geomatics, he's spent the past few years studying the electromagnetic drive, or EmDrive. Scientists have been puzzled for two decades after British scientist, Roger Shawyer, came up with the concept in 1999. But Dr McCulloch says he has "accidentally" chanced upon an explanation, saying it is evidence of his new theory of inertia.

The EmDrive is a fuel-free thruster system shaped like a cone, which uses microwaves to propel it through space. But why is it often dubbed the "impossible engine"?

It's all because of the conservation of momentum, which has been a rock solid part of physics for many centuries. It's the idea that you can't move anything without leaving something behind. So if you're sitting in your car, you can't push on the dashboard and suddenly the car starts rolling forward because as you're pushing on the dashboard, your backside is pushing on the seat the opposite way and so it cancels out. One way to move the car would be to throw your shoe out of the back window - that would be a reaction mass: something going backwards making the car move forward. This is what all of our technology is based on - the idea that in order to move forward or up, you have to push something out of the back. The thing about the EmDrive - and this is what is causing all of the fuss - is that it doesn't seem to be throwing anything out of the back; it's violating the conservation of momentum. In that sense, it should be impossible.

British scientist Roger Shawyer came up with the proposal for the EmDrive almost 20 years ago. When did you first come across the concept and were you surprised?

I wasn't especially surprised. I do remember seeing an article about it in *New Scientist* magazine around 2008 but I brushed over it because I was working on galaxies at the time, trying to explain galaxy rotation and things like that. It was only when NASA looked at it in 2014 and got a positive result that I decided there was something to it. I certainly wasn't surprised when NASA - or Eagleworks, which is the research team at NASA's Johnson Space Center - confirmed it in 2016. By then I'd applied my theory to it and it had worked.

You are well known for your new theory of inertia. Can you tell us a bit more about that?

I'm explaining inertial mass as being due to the zero-point field that quantum mechanics predicts. We know this exists because of the Casimir Effect [a small, attractive force that acts between two close, parallel, uncharged conducting plates]. Let's say a particle accelerates to the right. In this case, the information from far to the left can't get to it or catch up. That part of the universe is closed off to that particle but there is a horizon there that divides the hidden bits from the rest of the universe. This produces something called Unruh radiation and what I'm saying - which is new - is that the horizon on the left damps the Unruh radiation on the left of the particle. Since there is more Unruh radiation

"The great thing about the EmDrive is that it carries no fuel. It would make interstellar travel possible"

What is an EmDrive?

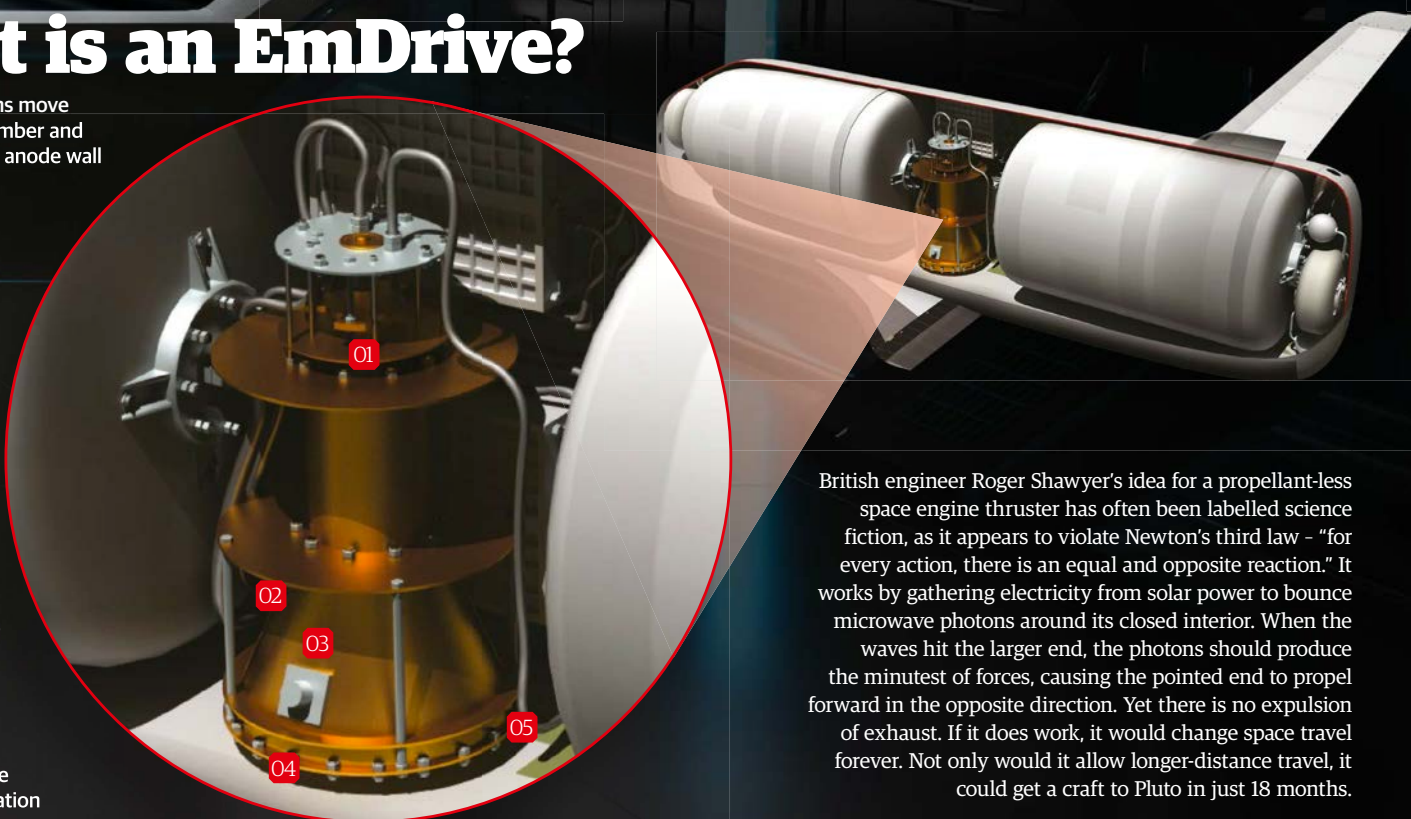
1 Emitted electrons move through the chamber and are collected by an anode wall

2 Propellant is injected and travels toward a discharge cathode

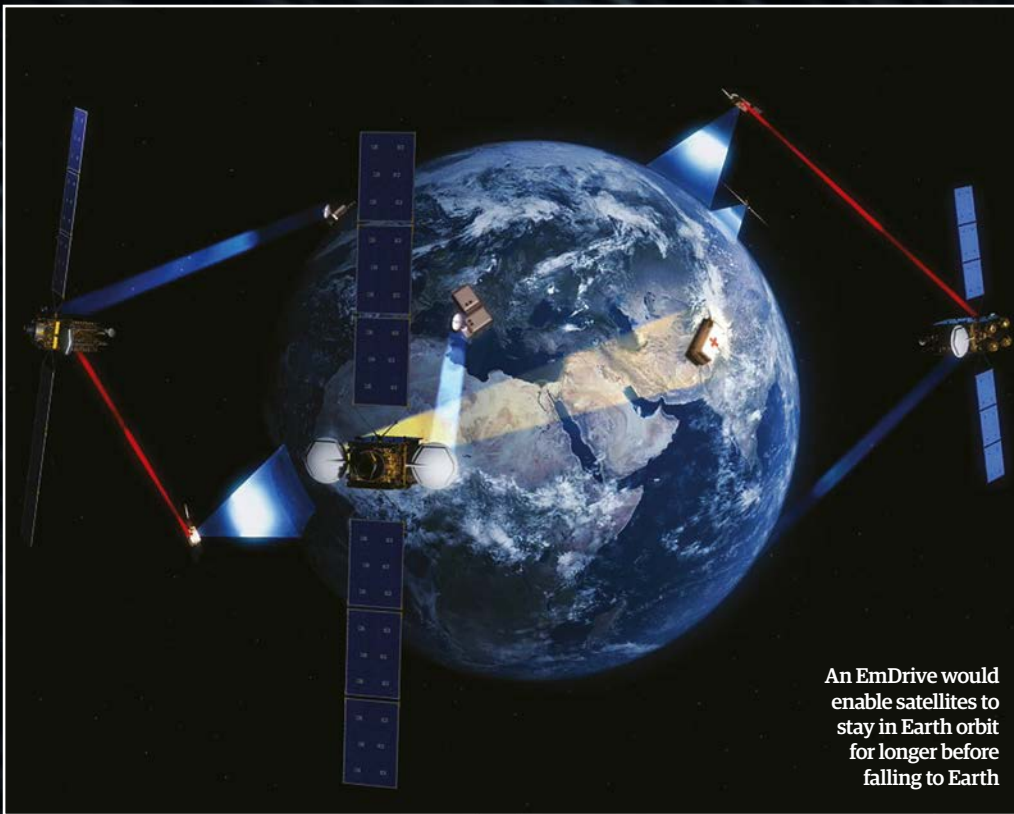
3 Electrons crash into propellant atoms to create ions

4 Ions are pulled out of the discharge chamber by ion optics

5 Electrons are injected into the beam for neutralisation



British engineer Roger Shawyer's idea for a propellant-less space engine thruster has often been labelled science fiction, as it appears to violate Newton's third law - "for every action, there is an equal and opposite reaction." It works by gathering electricity from solar power to bounce microwave photons around its closed interior. When the waves hit the larger end, the photons should produce the minutest of forces, causing the pointed end to propel forward in the opposite direction. Yet there is no expulsion of exhaust. If it does work, it would change space travel forever. Not only would it allow longer-distance travel, it could get a craft to Pluto in just 18 months.



An EmDrive would enable satellites to stay in Earth orbit for longer before falling to Earth

“The thing about the EmDrive is that it doesn’t seem to be throwing anything out of the back; it’s violating the conservation of momentum. It should be impossible”



An EmDrive would remove the need for huge masses of rocket fuel for travelling through space



This EmDrive was built by NASA's Eagleworks laboratory for testing in 2014

on the right, that pushes the particle back against its acceleration. For the first time, this produces a way of explaining inertial mass using a combination of quantum mechanics and relativity. That is interesting because those two things don't usually fit together.

How does this relate to the EmDrive?

For low accelerations, these Unruh waves are so big that they start being cancelled all the way around by the cosmic horizon, which is very far away. So only very low accelerations that have long Unruh waves can feel that horizon. I predicted that the inertial mass would decrease for very low accelerations and found that it exactly predicted galaxy rotation without dark matter. Now, if you think about this generally, it's saying the gradient in the zero-point field can produce motion. This is very much like the EmDrive because it is made up of a cavity with a wide end, which can allow a lot of zero-point field waves in it, and a narrow end where most of them are disallowed because they don't fit in the small end. You have a gradient there in a zero-point field, which I think is pushing the cavity. It is kind of rolling down a gradient in a zero-point field, almost like it's going down a hill.

Did you see this immediately when you began to investigate the EmDrive in 2014?

Well, the way I work is to look at the numbers and the anomalies and work out the process that may be causing them. I tend to just scribble on bits of paper to get an answer that looks plausible. Since my theory of inertial mass relies on the Hubble volume and shows that, depending on the size of the Hubble volume, the inertial mass changes, when I looked at the EmDrive, it was kind of familiar to me. It's almost like it has a large Hubble volume at the wide end and a smaller one at the narrow end. So I immediately picked up on that. I thought maybe the photons are losing and gaining mass as they swap between wide and narrow end.

Was it an almost accidental observation, then?

It was almost like a confirmation of what I was saying on a cosmological, galactic scale in the laboratory, which is something I'd been looking to prove for some time. But yes, this confirmation came out of the blue. It was like a eureka moment. I saw that it roughly fitted the data and it was very encouraging. It wasn't perfect, though. I'm now working on a paper where I've added dielectrics to the formula because some of the EmDrives had dielectrics in them and you have to treat those slightly differently.

So what are you saying is causing the propulsion - the movement from the narrow to the wide end of the EmDrive cavity?

In my explanation, what's happening is the photons are bouncing from the narrow end to the wide end many times. This is the Q factor, which is often given, which is 6,000 or more - that's how many bounces of photons you have going backwards and forwards. Every time they go towards the wide end, my theory states they gain inertial mass because there is more quantum vacuum at that end. An

“The photons are bouncing from the narrow end to the wide end many times. This is the Q factor”

analogy would be a person on a ship walking from the front to the back. At the front, they pick up a weight from the deck and carry it to the back and every time they walk to the front, they don't do anything. They just walk without a weight. So you can see there that the centre of mass of the ship is going to be shifted slowly towards the back. The ship will move very slightly forward as a result.

The model also relies on the speed of light varying within the EmDrive's cavity, doesn't it? Yes. It predicts that the speed of light varies within the cavity, although there is debate about this. I don't think it violates general relativity, although it's a very difficult thing to prove. You have to say space-time inside the cavity is being modified so a bug inside the cavity couldn't detect the variation in the speed of light. That would still fit with relativity.

Where do we go from this point, though? What other tests are being done and need to be done? NASA has now tested the EmDrive in a vacuum and so they can now rule out air currents. They now need to test it in a pristine environment such as space. The people who invented the Cannae Drive –

which is basically an EmDrive – including an Italian-American called Guido Fetta, are intending to put one up in space this year using a CubeSat. They're going to turn it on and see if its orbit changes in any way. That would be a good indication, for sure, especially as it's difficult to have a control test on Earth due to electromagnetic forces, electrical currents and things like that.

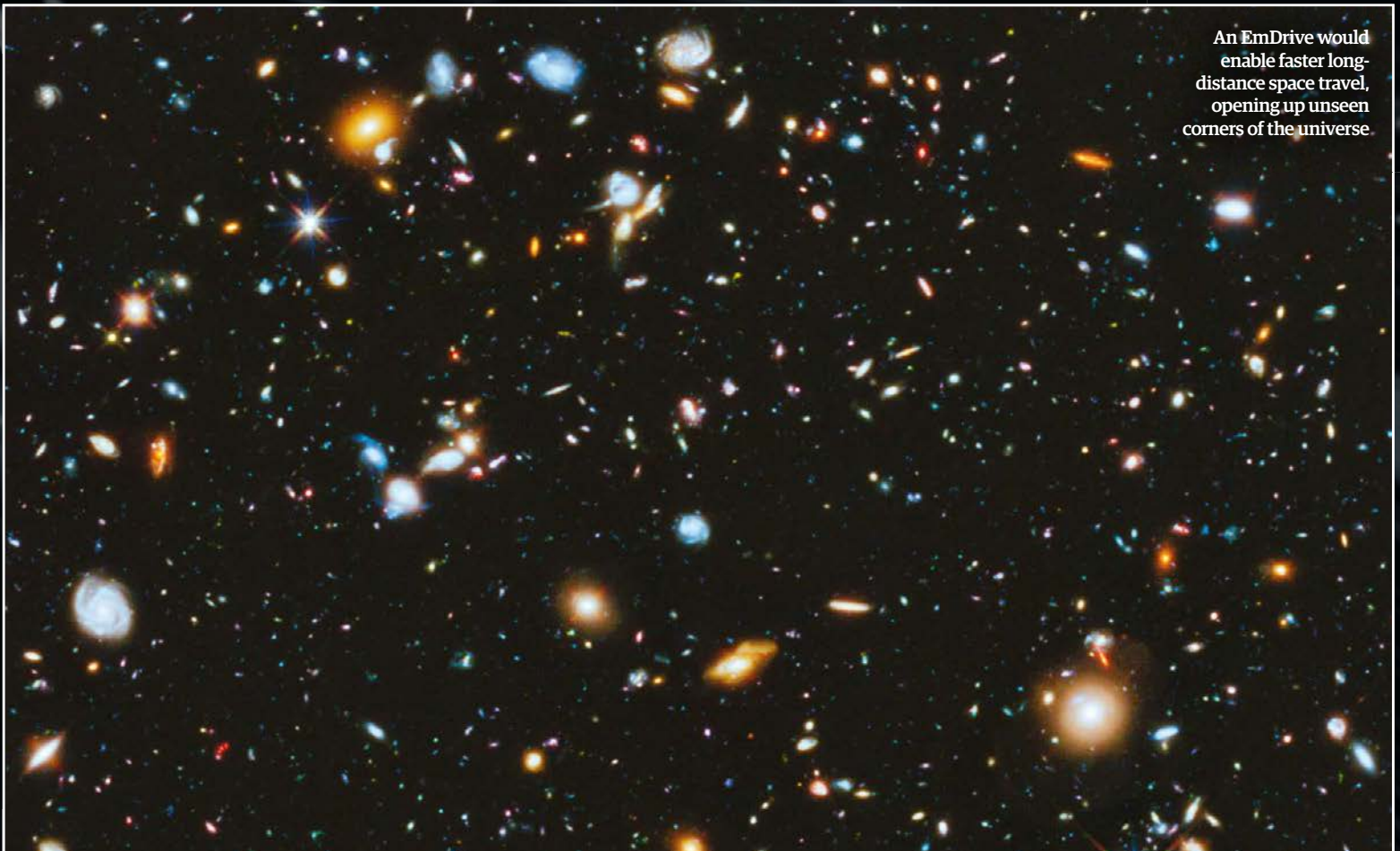
Would this be proof the EmDrive works, then? It would be a pretty good indication because there are a lot fewer effects in space that could cause this kind of thing because it's in a vacuum. The only problem would be to determine exactly how the orbit is changing so you'd have to position it very accurately using GPS or something like that.

If it was proved, how revolutionary could the EmDrive be? It would be extremely revolutionary. The problem with, for example, launching rockets for interstellar travel is you have to carry your fuel with you. So the rockets that are launched have to be huge and are also quite dangerous, given that they use a chemical explosion. It means you can't go to the nearest star

in a human lifetime because you have to carry a planet-sized amount of fuel to get close to the speed of light. But the great thing about the EmDrive is that it carries no fuel. It would make interstellar travel possible. You could launch satellites without the need for rockets using quite small launchers.

So it makes space more accessible? It would open it up. There are also applications on Earth. You could have floating cars and generate energy from it as well. Energy is coming in a new way from the vacuum. People have often said the zero-point field has lots of energy in it but we just can't get to it because it's uniform. But if this is true, then it's possible. If we could put a horizon in, we could make things move and generate energy.

So how far away are we from seeing this technology develop? My interest is in the science and not particularly in the business end of it. But it has been said that the Chinese have already tested it – whether or not that is true or not, I don't know. They claim to have sent it up on a satellite. I think the first use would be in satellite station keeping. At the moment, the engine is quite weak and the thrust quite small. You have to use a super-conducting cavity to improve it. You can put it on a satellite, which usually last ten to 20 years before falling down to Earth. This would be a small engine that would help keep them up a bit longer, so it could save quite a lot of money just in that way.



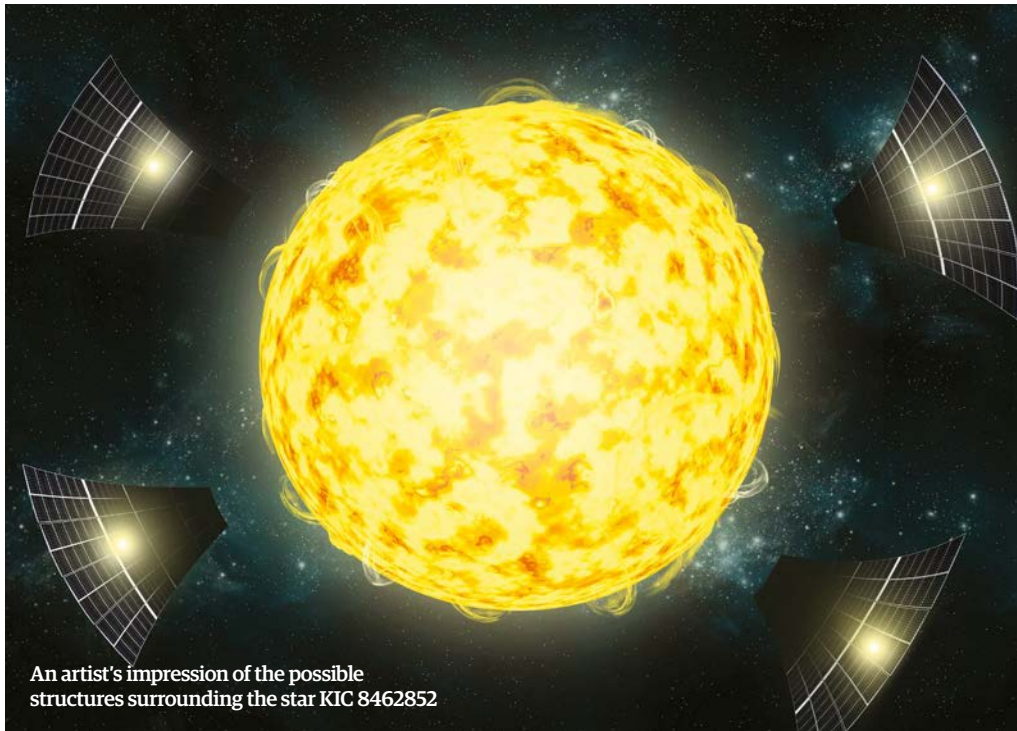
An EmDrive would enable faster long-distance space travel, opening up unseen corners of the universe.

What's causing the
STRANGEST
STAR
in the universe?

Space dust? Alien structures? Planetary collisions? The behaviour of Tabby's Star continues to inspire new ideas

Written by Paul Cockburn





"Somewhere, something incredible is waiting to be known," the wise American scientist Carl Sagan once said. Nor is it always where you expected. At first glance the star designated KIC 8462852 seemed nothing unusual, an ordinary hydrogen-fusing, F-type, main-sequence star slightly larger and hotter than our own (G-type) Sun. Located in the constellation of Cygnus, some 1,276 light years from Earth, it was just one among 145,000 stars observed by NASA's Kepler space observatory during the course of a four-year mission, looking for the tell-tale dips in brightness revealing orbiting exoplanets passing in front of their parent stars.

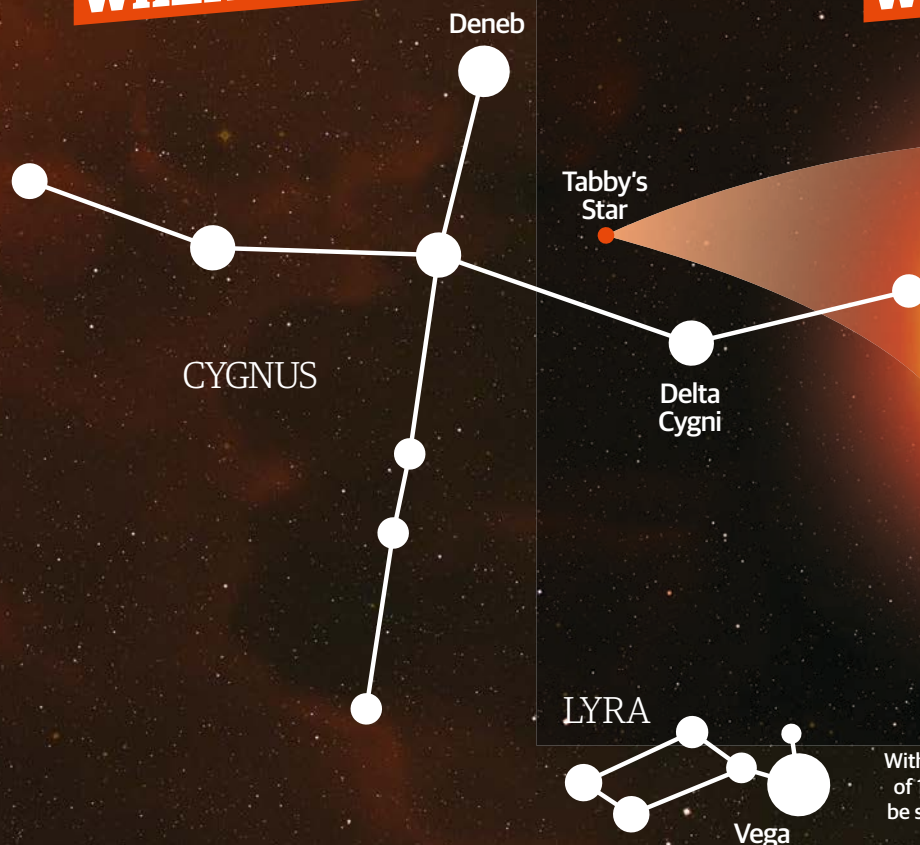
Thanks to the Planet Hunters project, however, KIC 8462852 data was flagged up as potentially interesting - though no one realised *quite* how interesting. "We'd never seen anything like this star," Louisiana State University astronomer, Tetha Boyajian tells **All About Space**. "We thought it might be bad data or movement on the spacecraft, but everything checked out."

In September 2015, as lead writer of a paper titled *Where's The Flux?*, Boyajian revealed that during the Kepler mission, the light from KIC 8462852 had mysteriously dipped in ways that simply did not match either a transiting exoplanet, or even

The weirdest star in the universe

Tabby's Star, also designated KIC 8462852, is over 1,000 light years away in the constellation of Cygnus

WHERE IS IT?



WHAT IS IT?



It's like our Sun
This hydrogen-fusing F-type star is roughly 1.4 times the mass of the Sun.



It's quite rare
Roughly one in 33 (3.03 per cent) stars in our immediate stellar neighbourhood are F-type stars.



Tabby's Star spits out light at odd intervals
The numerous dips in the light coming from Tabby's Star don't occur at regular intervals.



You can see it from Earth...
With an apparent magnitude of 11.7, Tabby's Star cannot be seen with the naked eye.



... but you would need a telescope
Tabby's Star is visible with a 5-inch (130mm) telescope, with low light pollution.

necessarily clouds of dust and gas; these "dips" in light had been irregular in terms of duration, regularity and brightness, with the loss of light ranging from 0.5 per cent to more than 20 per cent!

Boyajian's paper led to a succession of theories, ranging from an unusually large group of comets orbiting the star, to the headline-grabbing suggestion that the irregular dips in the light from KIC 8462852 - already nicknamed "Tabby's Star" after Boyajian herself - were positive proof that this particular star system was home to a technologically highly-advanced alien civilisation. To explain: back in the 1960s, renowned physicist Freeman Dyson argued that the energy demands of any intelligent civilisation would, within a few million years, outstrip whatever supplies were available on their home world. The most effective solution, he suggested,

would be to build a solar-panel structure to capture the star's light - this could start relatively small but then potentially grow until it covered the entire star, a concept now known as a 'Dyson Sphere'. So had Kepler been fortunate enough to start observing Tabby's Star as the aliens commenced building their equivalent of a Dyson sphere around it? The Breakthrough Listen programme at the University of California, Berkeley, turned their Green Bank radio telescope in the direction of Tabby's Star to see if they could detect any accompanying signals from the star system. (So far, nothing.)

In January 2016, however, Tabby's Star became even more puzzling. Bradley Schaefer of Louisiana State University had also turned his attention to KIC 8462852 but, instead of Kepler data, he used thousands of digitised sky photographs - originally

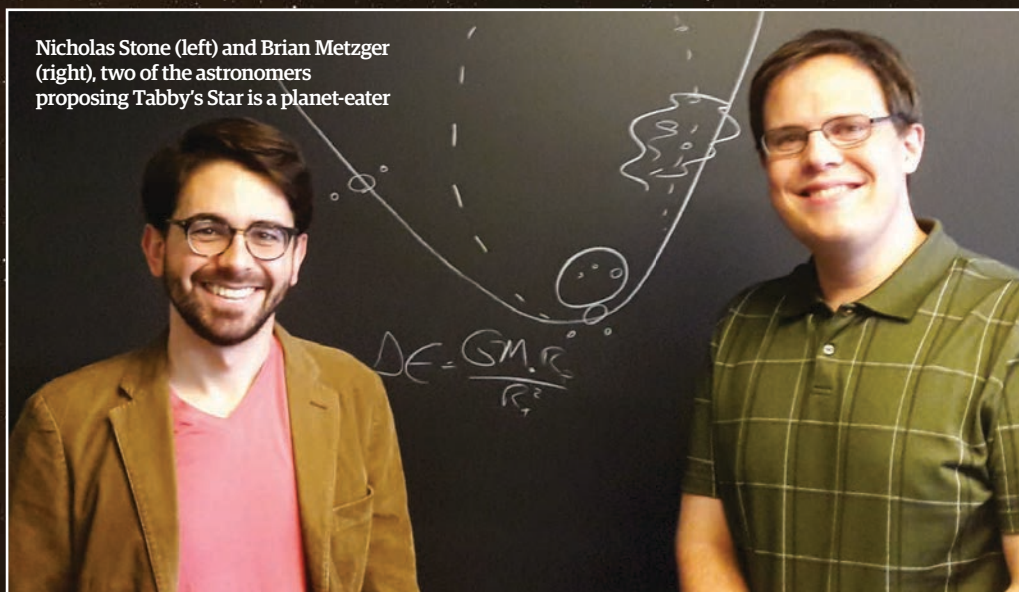
taken between 1890 and 1989 - held in the archives of Harvard College Observatory. According to his findings, Tabby's Star had dimmed by 14 per cent during the century. While there was some controversy over the accuracy of the data, Schaefer insisted he was correct and that "the dips shown by KIC 8462852 are still a profound mystery."

By summer 2016, Ben Montet - then of Caltech, but now a Carl Sagan Fellow at the University of Chicago - and Josh Simon, of the Carnegie Institution for Science, had carefully re-examined all the Kepler data and confirmed that Tabby's Star had also dimmed slightly during the four years of observation; by almost one per cent during the first three years, and then by a staggering two per cent in the following six months.

"It is unprecedented for this type of star to slowly fade for years," Montet said at the time. "And we don't see anything else like it in the Kepler data. This star was already completely unique because of its sporadic dimming episodes. But now we see that it has other features that are just as strange, both slowly dimming for almost three years and then suddenly getting fainter much more rapidly," Simon added. This combination of both sudden and gradual dips attracted the interest of Ken Shen of the University of

"We'd never seen anything like this star. We thought it might be bad data or movement on the craft, but everything checked out"

Astronomer Tabetha Boyajian, Louisiana State University



Green Bank Telescope, West Virginia, is the world's largest fully steerable radio telescope

WHY IT'S SO STRANGE

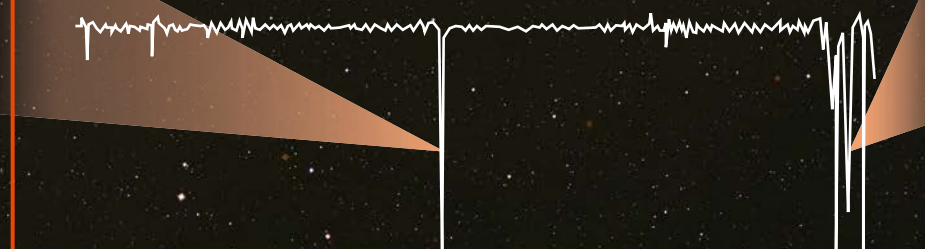
Random dips of light

Four years of Kepler observations include these random dips in the light curve, which aren't caused by transiting planets.



Day 793

This shows the dip in light that occurred on day 793 of the Kepler mission.



Days 1,490-1,580

These erratic dips were observed during a 90-day period near the end of the Kepler mission.

What could be causing Tabby's Star?

Several explanations have been suggested to explain the behaviour of KIC 8462852



Young star with material
Tabby's Star moves too fast to be part of the galaxy's youthful stellar population; nor are there infrared observations supporting the existence of a protoplanetary disc that might irregularly block out the star's light. Spectral emission lines suggest it's not a young star.

✗ UNLIKELY



The star ate a planet
A large mass sinking into the outer layers of a star releases gravitational energy that could cause an unobserved brightening; a subsequent return to the star's original state might then be seen as a gradual dimming. Debris could orbit the star for some time.

✓ POSSIBLE



Field of planetary debris
A field of planetary debris, the remains of planet-on-planet collisions, could block light but would also create a dust cloud visible in infrared wavelengths. Successive observations have failed to discover this debris; the chance of us observing it as it happens seems minuscule.

✗ UNLIKELY



Artificial megastructure
This requires the existence of intelligent aliens that are technologically and sociologically advanced enough to build epic megastructures wider than planets. Such civilisations are expected to give off signals, which Earth-based SETI scopes could detect.

✗ UNLIKELY



A cloud of comets breaking up
We observed Comet Shoemaker-Levy 9 breaking apart around Jupiter, so it could happen around a star. A group of comets might produce the long-term light signatures Kepler detected, but spotting it as it happens seems unlikely.

✓ POSSIBLE

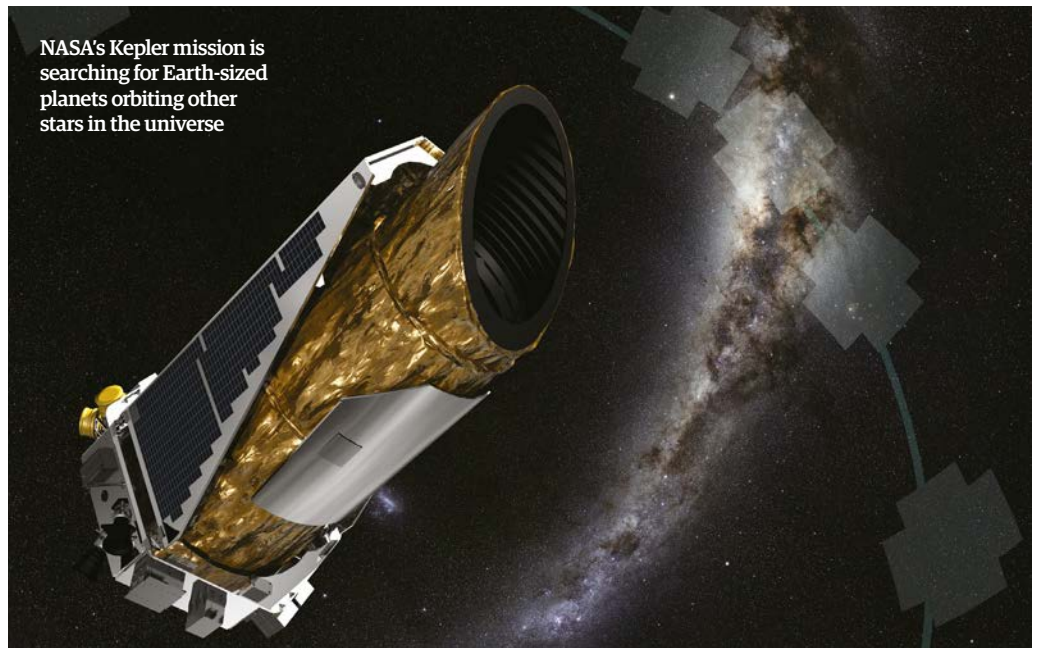
California, Berkeley, and Brian Metzger and Nicholas Stone of Columbia University, New York. "Two separately unusual phenomenon are not usually found in concert unless they are somehow related," says Metzger. "But none of the previous explanations for Tabby's Star could address both observations."

In January 2017, the three astronomers suggested that some kind of planetary collision with Tabby's Star was to blame: the gradual dimming of KIC 8462852 was possibly the star reverting to its pre-collision state, while any more recent and erratic dimming episodes were likely caused by light-absorbing debris. According to their paper, the planet in question could be either a rocky, Earth-like world (which, in the process of its destruction, would see its mantle ripped away, leaving hot gas and dust material in orbit around the star), or a massive Jupiter-sized planet, which might leave some of its moons to be subsequently torn apart by the star's gravity.

"If the Schaefer result turns out to be correct, then we require a fairly massive planet similar to the Earth or larger to have been consumed to explain at least century-long dimming," says Metzger. "If the Montet and Simon result holds up to further scrutiny, the gradual dimming over just the last decade could be explained also by the consumption of a smaller planet, similar in mass to the Moon. Our idea would apply as long as either the Schaefer or Montet and Simon theory is confirmed."

For the time being, though, "Tabby's Star - Planet-eater" remains just a theory, but what further evidence could either confirm or dismiss their idea? "If the transiting debris or moons responsible for the dips are directly connected to the planet disruption events, as we hypothesise, then - at least in two of our scenarios - we predict that the pericentre radius (the radius of closest approach) of the transiting debris is very close to the stellar surface," says Metzger. "This is also likely to be close to the part of the orbit where we are observing the transit dipping events. The next time a big transit dip is observed

NASA's Kepler mission is searching for Earth-sized planets orbiting other stars in the universe



"Two separately unusual phenomenon are not usually found in concert unless they are somehow related" **Brian Metzger, Columbia University**

from Earth, we should therefore expect significant out-gassing (the release of gas dissolved, trapped, frozen or absorbed in other materials) and dust to be released from the debris or moons. This should produce a temporary flare of infrared emission, as the dust is heated, lasting for a few days to a few weeks, which might temporarily vanish as the objects pass closest to the star due to the dust being evaporated."

Metzger adds, "Another prediction of our model is that if another moon or planet impacts and sinks

into the star, then we might expect a temporary 'brightening' of Tabby's Star, followed by another decay in its light curve." So, to paraphrase Carl Sagan, something possibly incredible is waiting to be known about Tabby's Star, but we'll only likely know about it if we keep watching. "Telescopes across the electromagnetic spectrum (radio, infrared, optical, X-ray) should be pointed towards the star when this happens to look for any signs of interaction between the star and its debris," Metzger says.

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Explorer's Guide Charon

Far out on the edge of our Solar System sits the largest of Pluto's five natural satellites, an imposing celestial mystery all on its own

In the summer of 2014, the New Horizons spacecraft had awakened from hibernation, its course corrected for an encounter with one of the remotest planetary bodies in the Milky Way. As Pluto began to emerge from the deep dark of space, so did another bright neighbour - the imposing moon, Charon.

Named after the boatman who carried souls down the river Styx into the underworld of Greek mythology, Charon stands as a relatively new discovery, first recorded in 1978. The largest of Pluto's satellites, Charon has remained one of astronomy's most intriguing mysteries. Some scientists argue it was formed around 4.5 billion years ago, the product of a monumental collision between Pluto and a large object from the Kuiper Belt - much like the one that supposedly tore the Moon from the Earth.

While its origins remain something of a mystery, the lack of an icier surface on Charon combined with a rockier topography than Pluto suggests the satellite may have collided with Pluto before entering orbit around it. The impact could have superheated the

satellite, effectively boiling off methane ices without tearing either Charon or Pluto apart.

Despite being a moon in a Solar System full of incredible sights, Charon is a fascinating object. Technically, Charon doesn't actually orbit Pluto - instead, the two are bound in a gravitational lock that sees its barycentre (centre of mass) located outside of either body. Such a relationship has led some to theorise Charon and Pluto are actually merged in a binary system of sorts.

Another of its famous characteristics is a large dark area in its north polar region, thought to be caused by condensed gases that have been expelled from Pluto's volatile atmosphere. The hemisphere itself is pockmarked with craters, while the south is noticeably smoother, suggesting the moon has experienced a massive resurfacing event that caused the southern hemisphere to differentiate.

How to get there

2. Passing the Red Planet

After four months in space, you'll tear past Mars and its red, pockmarked surface. For the next nine months or so the craft itself will begin small course corrections.

3. A date with Jupiter

Just over a year after launch, you should be on course to encounter the gaseous shadow of Jupiter. You've now travelled 588mn km (365mn mi) from Earth.

1. Take off

To reach the very outskirts of our corner of the cosmos you're going to need a rocket powerful enough to breach the Earth's atmosphere, such as the Atlas V that carried New Horizons.

4. An interplanetary odyssey

The next seven to eight years are relatively uneventful as the craft goes into a form of hibernation, awakening every 50 days or so to perform diagnostics and maintain its spin.

5. From Pluto to Charon

Following ten years and more than 4.8bn km (3bn mi), you'll finally reach Pluto, its moon Charon and the scattered remains of the Kuiper Belt.

(Leia) Organa Crater

Gallifrey Macula

Tardis Chasma

How big is Charon?

The impressive moon partially orbiting Pluto has a diameter somewhere between 1,207 and 1,211 kilometres (750 and 753 miles), which is roughly the same as the distance between Indianapolis, United States, and Cadiac, Quebec, Canada.

Canada

USA

Indianapolis

Cadiac

Charon

Kubrick Mons

Serenity Chasma

Vulcan Planum

Clarke Mons

Kaguya-Hime Crater

Vader Crater

Mordor Macula

How far is Charon?

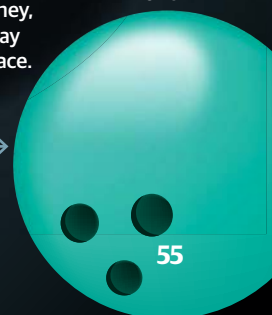
Based on the New Horizons data and its decade-long journey, Charon is around 4.8 billion kilometres (3 billion miles) away from Earth. Such a distance accounts for Charon's icy surface.

Charon



If Charon were a 2cm (0.8in) wide marble, then the Earth would be the size of a bowling ball some 82km (51mi) away!

Earth



Top sights to see on Charon

It may be found in the furthest reaches of the Solar System but that doesn't mean this icy satellite is any less fascinating than the other moons found in our very own corner of the cosmos. From deep ravines that could swallow up Mount Everest to powerful cryovolcanoes that spit freezing materials into the wintry atmosphere, the largest of Pluto's orbital neighbours holds many exciting features.

Mordor Macula, named after the volcanic realm of Sauron in Tolkien's epic *The Lord Of The Rings* saga, is perhaps Charon's most striking region. From afar it resembles a shadowed blot, a Jovian spot on the moon's icy surface, and it remains the most discussed and debated feature discovered by the New Horizons probe. It wasn't until the publication of a paper in the academic journal *Nature* that the dark, bloodstain-esque blotch was revealed to be condensed gas and other flotsam

material ejected from the grip of Pluto's atmosphere. These gases, which include methane, nitrogen and carbon monoxide, solidify when exposed to the harsh temperatures of the moon's 'winter' period. When these frozen forms are subjected to waves of solar radiation and the moon's warmer months, they evaporate leaving behind large deposits of a heteropolymer molecule known as tholin. It's this irradiated molecule that possesses the brown, rust-like colour that 'Mordor' has become famous for.

Charon is also a patchwork of craters, chasms and other geological minutia, most of which have been named after famous characters, places and objects from science fiction. Only on Charon will you be able to visit the crater triumvirate of Organa, Skywalker and Vader, walk the logically minded plain of Vulcan Planum, or travel like a leaf on the wind down Serenity Chasma.

There are also a number of large mountains and volcanic structures spread across the face of Charon. All of these are either active or dormant cryovolcanoes, typically categorised with the Latin term 'Mons'. There are three mountains of note on Charon - the largest, Butler Mons, is named after American sci-fi novelist Octavia E Butler, and is joined by Kubrick Mons and Clarke Mons.

However, not every feature on the icy surface of Pluto's largest moon Charon has a pop culture moniker - in fact, one attraction remains nameless yet offers up one of the moon's most enticing and puzzling mysteries. Known as the 'mountain with a moat', this structure shows a large 'mons-esque' structure rising from a moat-like depression. No other mountainous structure shares such a trait, leaving scientists baffled as to the geological nature of its origin.

Nostromo Chasma

With a title taken from the ship piloted by Ripley and her crew in the sci-fi classic *Alien*, the Nostromo Chasma is a large rift valley in Ripley Crater.



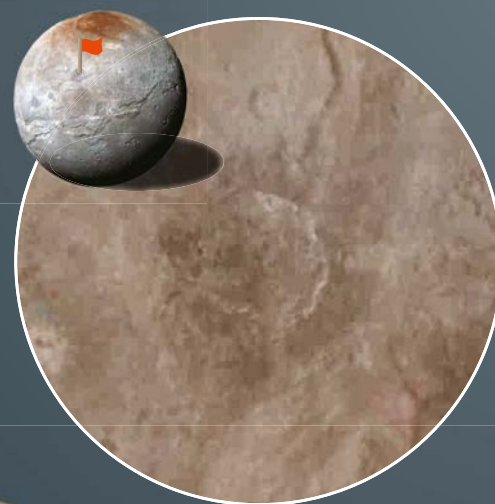
Vader Crater

Named after the iconic masked villain from the *Star Wars* saga, the Vader Crater is located close to Organa Crater and Skywalker Crater.



Ripley Crater

One of the clearest impact craters on the surface of Charon, the Ripley Crater was named after the famous heroine from *Alien* by the New Horizons team.



Mordor Macula

The largest macula (or darkened area) on the surface of Charon, Mordor is around 475km (295mi) in diameter and is located in the moon's northern polar region.



Charon in orbit

Pluto and Charon aren't engaged in a traditional orbital relationship - the two are instead bound in a gravitational lock that sees the same side of each planetary body always presented to the other. It takes Charon and Pluto 6.4 days to complete an orbit of one another, creating a mutual tidal locking between the two. The distance between Pluto and Charon is around 19,570 kilometres (12,160 miles).

Pluto



Charon



1 Charon day = 6.4 Earth days
1 Charon year = 248 Earth years

The relative reflectivity, size, separation, and orientations of Pluto and Charon are approximated in this composite image



Weather forecast

-220°C
-364°F



Like much of Charon's geological identity, the moon's atmosphere has been partially absorbed from gases expelled from Pluto. Its atmosphere mainly consists of nitrogen and methane, with other gases regularly emitted by Charon's many cryogeysers and cryovolcanoes. Its surface is an incredibly cold -220 degrees Celsius (-364 degrees Fahrenheit), and even colder in 'winter', but radioactive rays often batter its polar ice caps.

Charon in numbers

1.55×10^{21}

The estimated mass of Charon, measured in kilograms

The number of days it takes Charon to complete one orbit of Pluto

6.4

Number of moons orbiting Pluto - Charon, Styx, Nix, Hydra and Kerberos

-258°C

The average winter temperature on Charon's poles

1978

The year Charon was discovered

9km

The estimated depth of one of Charon's deepest canyons, Argo Chasma

1,207.2km

The estimated diameter of Pluto's largest moon

Discovery of Uranus' rings

This month marks 40 years since we realised rings could exist around worlds other than Saturn

On the evening of 10 March 1977 two teams of astronomers using the Kuiper Airborne Observatory and the Perth Observatory in Australia settled down to watch a spectacular and rare event: Uranus pass in front of star SAO 158687, a transit that would provide the perfect chance to observe a distant world. On that night, however, they didn't just get to see the ice giant; they managed to make a major discovery - a ring system around Uranus.

How the astronomers confirmed the rings, which the Kuiper Airborne Observatory named as Alpha, Beta, Gamma, Delta and Epsilon and the Perth team identified simply as rings one through to six, was from a trick of the light - SAO 158687 blinked as each of the rings blocked out its starlight. As the Kuiper team had a much better vantage point, they published their results first meaning that astronomers James Elliot, Edward Dunham and Jessica Mink are credited with the discovery of the Uranian rings.

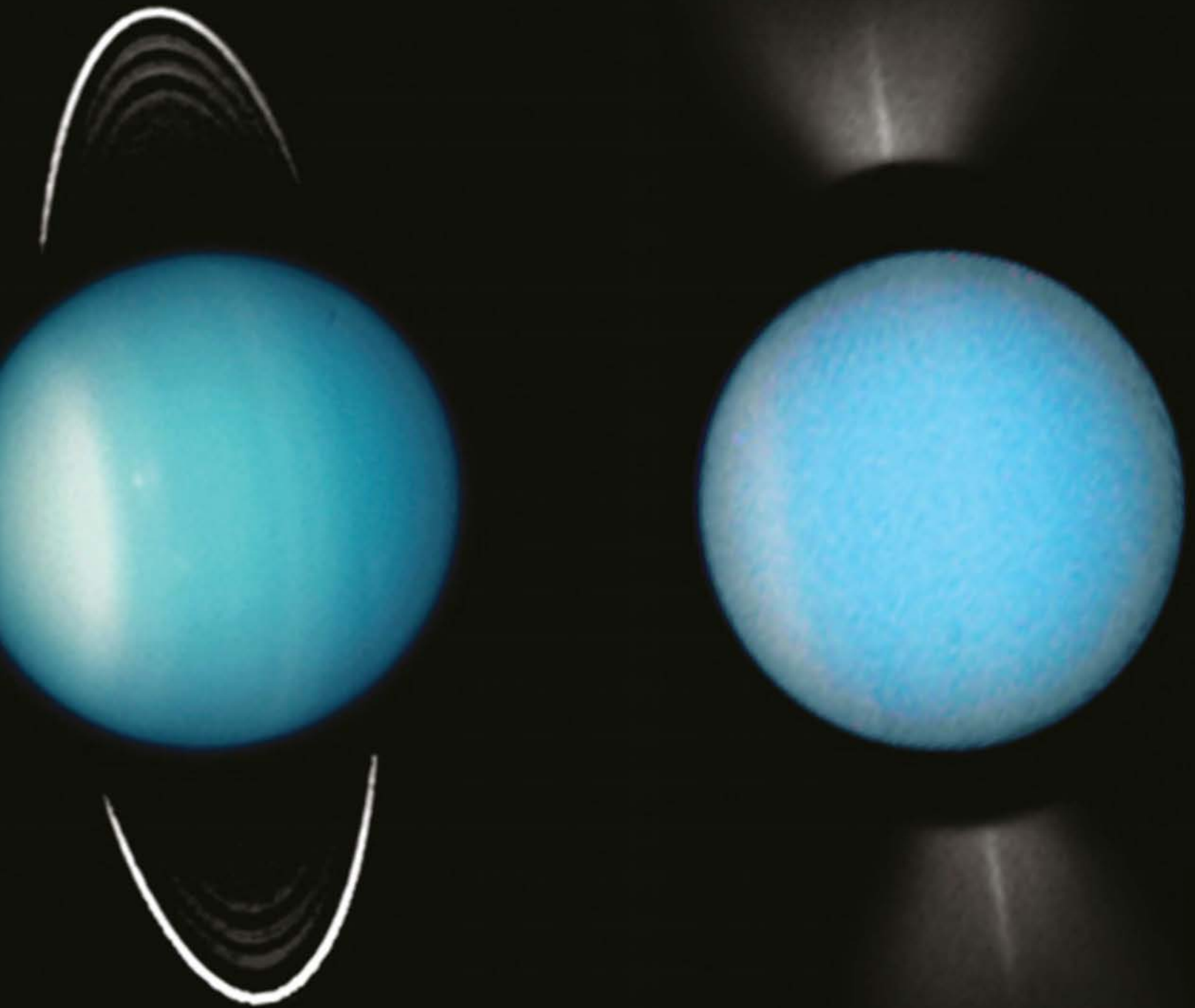
Today - and thanks to images from NASA's Voyager 2 and Hubble Space Telescope - we know Uranus to have 13 rings, most only a few kilometres wide, no more than 600 million years old, and thought to have originated from the collision and fragmentation of a number of moons.

NASA's Kuiper Airborne Observatory (pictured) confirmed the existence of the Uranian rings in 1977



Rings of Uranus

Uranus and its rings
as captured by NASA's
Hubble Space Telescope
in 2005, 2003 and 2007



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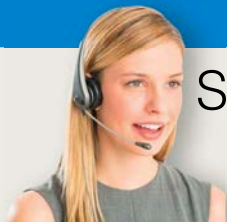
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Sophie Cottis-Allan



**National Space Academy
Education Officer**
Sophie studied
astrophysics at
university. She has
a special interest in
astrobiology and
planetary science.

Josh Barker



**Education Team
Presenter**
Having earned a
master's in physics
and astrophysics, Josh
continues to pursue his
interest in space at the
National Space Centre.

Gemma Lavender



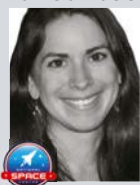
Editor
Gemma holds a master's
degree in astrophysics,
is a Fellow of the Royal
Astronomical Society
and an Associate
Member of the Institute
of Physics.

Robin Hague



Science Writer
Robin has a degree
in physics with space
technology and a
master's in hybrid rocket
engine design. He
contributes regularly to
All About Space.

Tamela Maciel



**Space Communications
Manager**
Tamela has a degree in
astrophysics and writes
for the National Space
Centre Blog. She has
eight years' experience in
science communication.



Mars

Mars sits at the edge of the habitable zone. Recent evidence shows there was water on the surface billions of years ago, and there are still dribbles of water there today. But we still don't know if it did, or still does, host life.



Ganymede

Recent evidence suggests Ganymede plays host to an underground saltwater ocean beneath its crust. Ganymede is the only moon with its own magnetic field - ours is vital for keeping us safe from harmful radiation from the Sun.



Enceladus

Like Jupiter's icy moons, Enceladus appears to have a vast ocean beneath its frozen surface. It is thought to have hydrothermal vents at the bottom of its ocean, with vast plumes of liquid spraying out from its poles into space.



Europa

Europa is an icy satellite believed to have a vast, deep ocean beneath its crust. Here, life would be protected from radiation, while its eccentric orbit pushes and pulls the core, providing a heat source on the seabed.



Which worlds in the Solar System could host life?

Jack Lewis



Titan

Titan is the only other body in the Solar System known to have liquids on its surface; these are not water but liquid hydrocarbons, methane and ethane, forming seas and lakes. Could life as we don't know it survive here?



Venus

Venus is a hot and inhospitable world at 462°C (864°F), but billions of years ago it might have been more temperate - a region 55km (34mi) above the surface has the most Earth-like conditions in the Solar System.



Triton

Triton, the largest moon of Neptune, is thought to have a rocky core and, between this and the surface, there could be an ocean of water lurking. Triton is also one of the few moons known to be geologically active.



Callisto

Callisto is the furthest of Jupiter's Galilean moons and is subjected to the least amount of radiation. Its surface appears to be very ancient but with very little activity, aside from asteroid and comet impacts.

SPACE EXPLORATION

What would happen if an astronaut's tether broke on a spacewalk?

David Todd

Depending on the exact scenario, probably not much. Without external forces an untethered astronaut would continue to orbit and move round the Earth at the same speed as the space station or spacecraft they had been previously tethered to. However, if the tether and astronaut weren't experiencing any unexpected external forces it is unlikely that the tether would just break.

It is feasible to imagine a situation where the astronaut is being pulled away from the spacecraft and the tether snaps under the strain. In this case, they would likely move in the direction they were being pulled. This would alter their orbit depending on the size of the force. **TM**

Astronauts are tethered to the craft when conducting spacewalks



DEEP SPACE



Our Sun is considered to be a fairly average star

Are suns and stars different objects?

Rosie Taylor

On a physical basis, there is no difference between a star and a sun. The Sun is a star like all the others; it is a gigantic ball of burning gas. The Sun is just a name that we give to our star, as it helps us to identify it with no confusion. The difference in name came from a time in which we thought there might be some fundamental differences between the Sun and the stars.

While technically the same, we do find that stars do in fact vary. They are not all identical copies of each other, and stars have a range of temperatures, sizes and compositions. Alongside this, stars change as they age, so stars can appear different as they progress through their lifecycles. Our Sun is a fairly average star in terms of its size and temperature when compared to the rest of the known stars in the universe. **TM**



Each star emits the same amount of light, regardless of location

ASTRONOMY

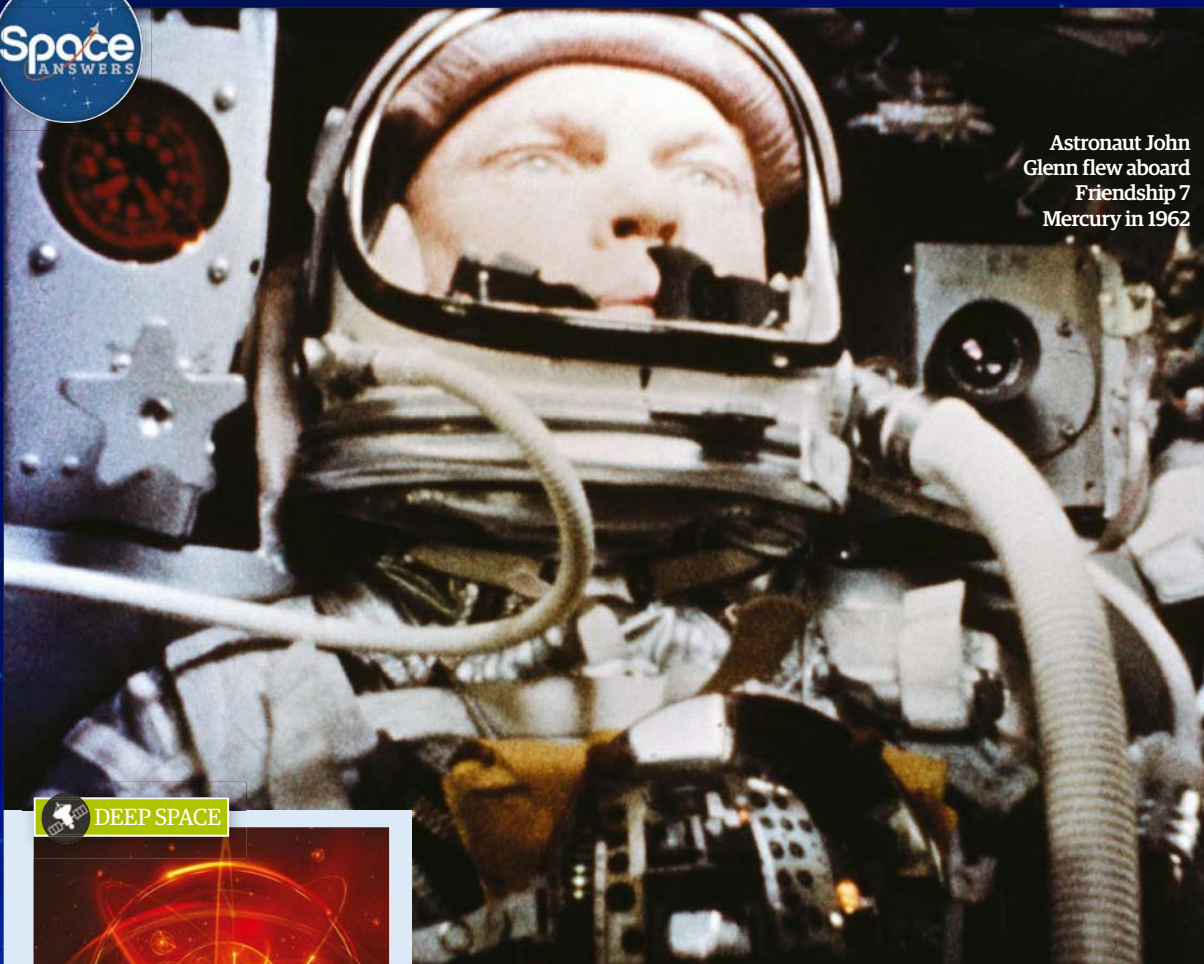
If you put all of the stars in the night sky together, how bright would Earth's sky be?

Mike Reynolds

The sky would be about as bright as it is now. Regardless of where the stars are positioned in our night sky, they would still output the same amount of light. This total output across the entire night sky would remain constant if the stars weren't

themselves changed. This is, of course, assuming we simply move the stars so they all appear to be next to each other in the night sky. If we moved them so they occupied the same space, they would collapse under the collected mass and become a black hole. We could observe a change in

brightness if we changed the distance between the Earth and the stars we see - as they got closer brightness would increase, and as they moved away brightness would decrease. However, altering the universe on that sort of scale may have more issues than just a brighter night sky for us. **JB**



Astronaut John Glenn flew aboard Friendship 7 Mercury in 1962

SPACE EXPLORATION

What were the 'fireflies' astronaut John Glenn saw?

Fiona Williams

In 1962, John Glenn made history by becoming the first American to orbit the Earth. But his mission, on-board the Friendship 7 Mercury, became infamous for another reason. During his mission, Glenn reported to Mission Control: "This is Friendship 7. I'll try to describe what I'm in here. I am in a big mass of very small particles that are brilliantly lit up like they're luminescent. I never saw anything like it. They're round a little; they're coming by the capsule, and they look like little stars... a whole shower of them." Many people speculated as to what these dancing space lights could be. The mystery was solved on the next Mercury flight when Scott Carpenter identified them as snowflakes - tiny white pieces of frost produced by frozen condensation warming up in the Sun's light. **SA**

DEEP SPACE



Black holes are created when material is squashed into a tiny space

What would happen if you fed antimatter into a black hole?

David Hunt

If antimatter fell into a black hole it would behave the same as matter. Experiments down here on Earth have shown that antimatter still obeys the laws of gravity and as such, would still be pulled into a black hole and be constrained within the event horizon.

As we can't take measurements from inside a black hole it is difficult to know exactly what occurs inside these exotic objects. If there is matter within the black hole, the antimatter would annihilate with it releasing energy, however, this energy would still be unable to escape the event horizon. Stephen Hawking's Hawking radiation actually relies on antimatter falling into a black hole to allow the radiation to escape, so it is assumed this occurs fairly often. **TM**

ASTRONOMY

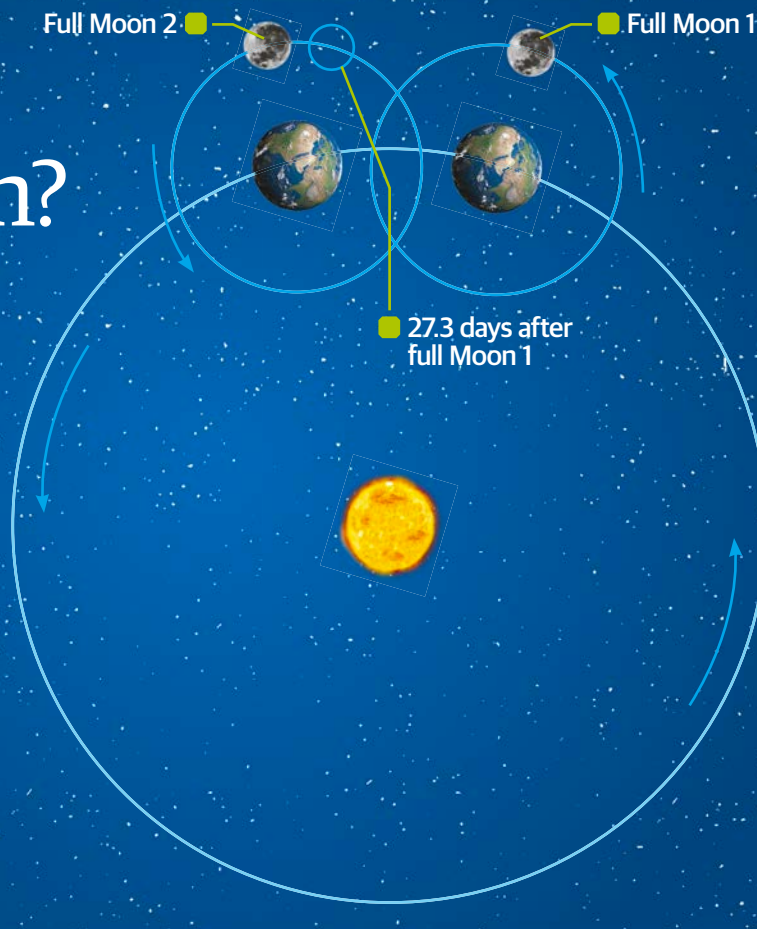
What is a blue Moon?

Matthew Hughes

The term 'blue Moon' is somewhat misleading. The name actually has nothing to do with the colour of the Moon; in fact, a blue Moon is the name of the third or fourth full Moon in a season. This is often simplified down to be the name of the second full Moon in a single month. We get a full Moon roughly once every 29.5 days. As a result of this being just shorter than a month, we usually see one full Moon in a month.

However, on occasion things can line up such that two full Moons can occur within one calendar month. This is not something that happens very often and the next time a blue Moon will be visible here in the UK will be January 2018; the first full Moon will be on 2 January, while the second full Moon will fall on 31 January. **JB**

Full Moon 2 Full Moon 1



DEEP SPACE

What is a flat universe?

Jamie Carter

A 'flat' universe refers to the overall geometry of our universe. It doesn't literally mean the universe is a single flat sheet, rather that the way it behaves is equivalent to something we could call flat. Because of this

there are certain fundamental properties we can expect. For example, in a flat universe parallel lines never converge. We also know that in a flat universe the corners of cubes will always be right angles, and the angles in a triangle will

add up to 180 degrees. Now these may seem obvious to you if you have studied any geometry before, however, if we were in a non-flat universe, we would have a different geometry and these fundamental rules would be different. **JB**

Saddle universe



Closed universe



Flat universe

In a flat universe parallel lines never converge



The skies on Titan when standing on its surface would be a thick, burnt orange

SOLAR SYSTEM

What colour is the sky on Titan?

Leigh Kimball

Thanks to the Cassini-Huygens mission to Saturn's largest moon, Titan, we have been able to see direct images of its skies. The images beamed back show the sky to be a light tangerine colour - but that was partly thanks to camera trickery.

An astronaut standing on the surface of Titan would observe the skies to be a hazy, dense, dark orange. Titan's atmosphere is much thicker than the Earth's with large amounts of methane. You certainly would not enjoy any planet rises since Titan is much further away from the Sun than the Earth, and this results in the surface only receiving a small fraction of the light that our planet does. To a viewer on the surface it would never get brighter than twilight. **SA**

SOLAR SYSTEM

Is it true that the planets don't actually orbit the Sun?



Ben Couchmann

For all practical purposes, yes, the planets orbit the Sun. However, if you want to get incredibly technical the centre of rotation isn't the centre of the Sun's mass. To explain this, we have to look at something called barycentres. A barycentre is the centre of rotation of two (or more) masses. The force of gravity works both ways, so as the planets are being pulled towards the Sun, the planets

are pulling back. This causes the Sun to wobble as it spins. This centre of rotation can end up outside of the Sun's photosphere depending on the position of the planets. This wobbling of the parent star is used to identify exoplanets when studying other stars.

A wobbling star suggests that another object may be present and if measured accurately enough, we can even calculate the size of these orbiting objects. **TM**

How have comets been found?

The largest comets are easily visible to the naked eye but with more than 4,000 listed, most can only be spotted with Earth- and space-based telescopes

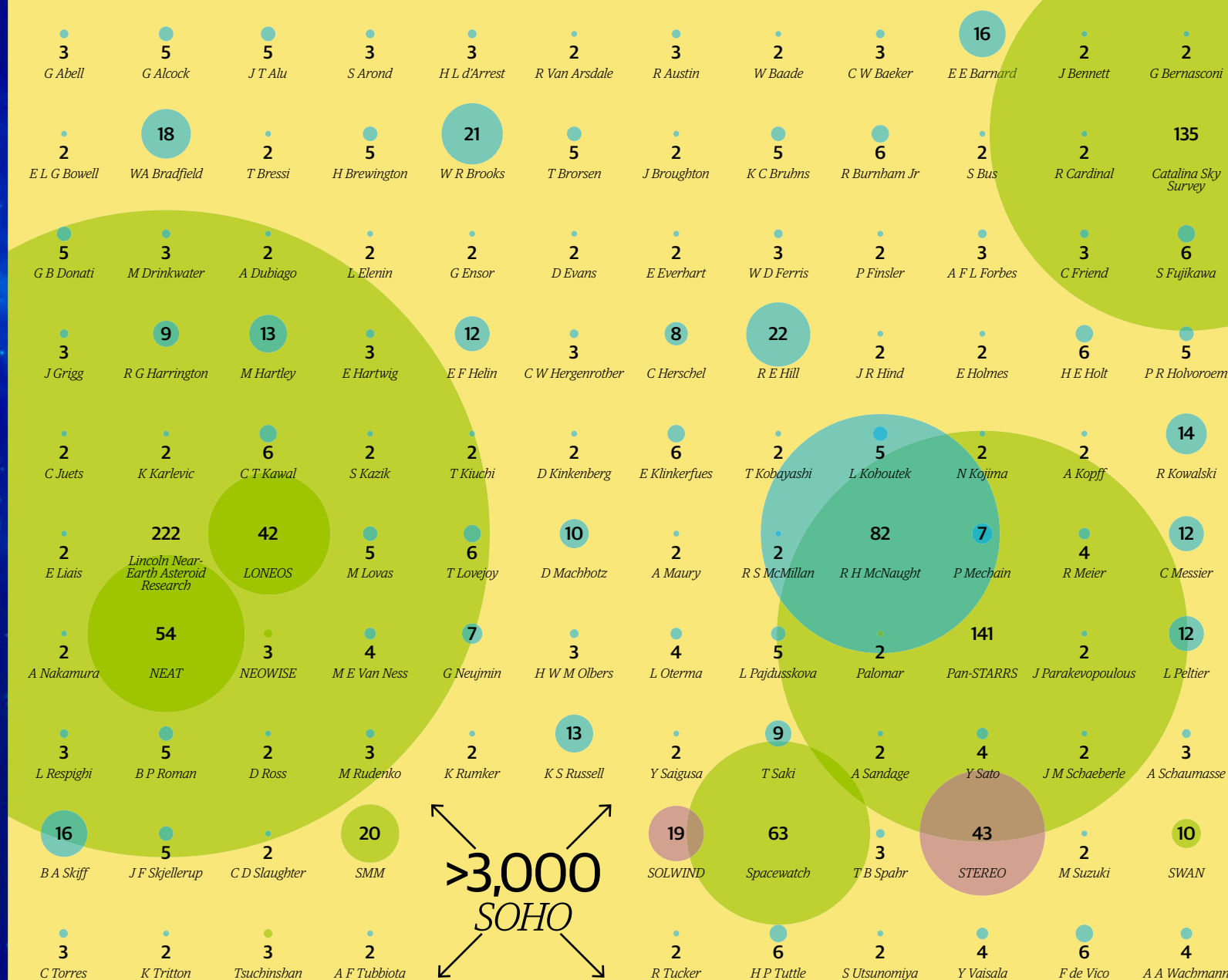
Jenna Llewellyn

Comets have been known since antiquity, with the occasional large naked-eye comets being taken for celestial warnings and harbingers of calamity; the ancient Greeks were the first to consider them scientifically, and suggested that they might be atmospheric phenomena. It was not until the famous Danish astronomer Tycho Brahe compared the apparent position of the Great Comet of 1577 from

different locations that comets were shown to be outside the Earth's atmosphere. Still it was disputed what they were and how they were moving; it was Newton's work on gravity that finally showed how the observed behaviour matched that of an object moving in a parabolic orbit. Then in 1705, Edmund Halley - who would later become Astronomer Royal - used Newton's theories to determine that the great comets of 1531, 1607 and 1682 were actually the same

comet, and successfully predicted its return in 1758. Although he didn't live to see the comet prove him right, it was named after him and Halley's Comet has become the best known example.

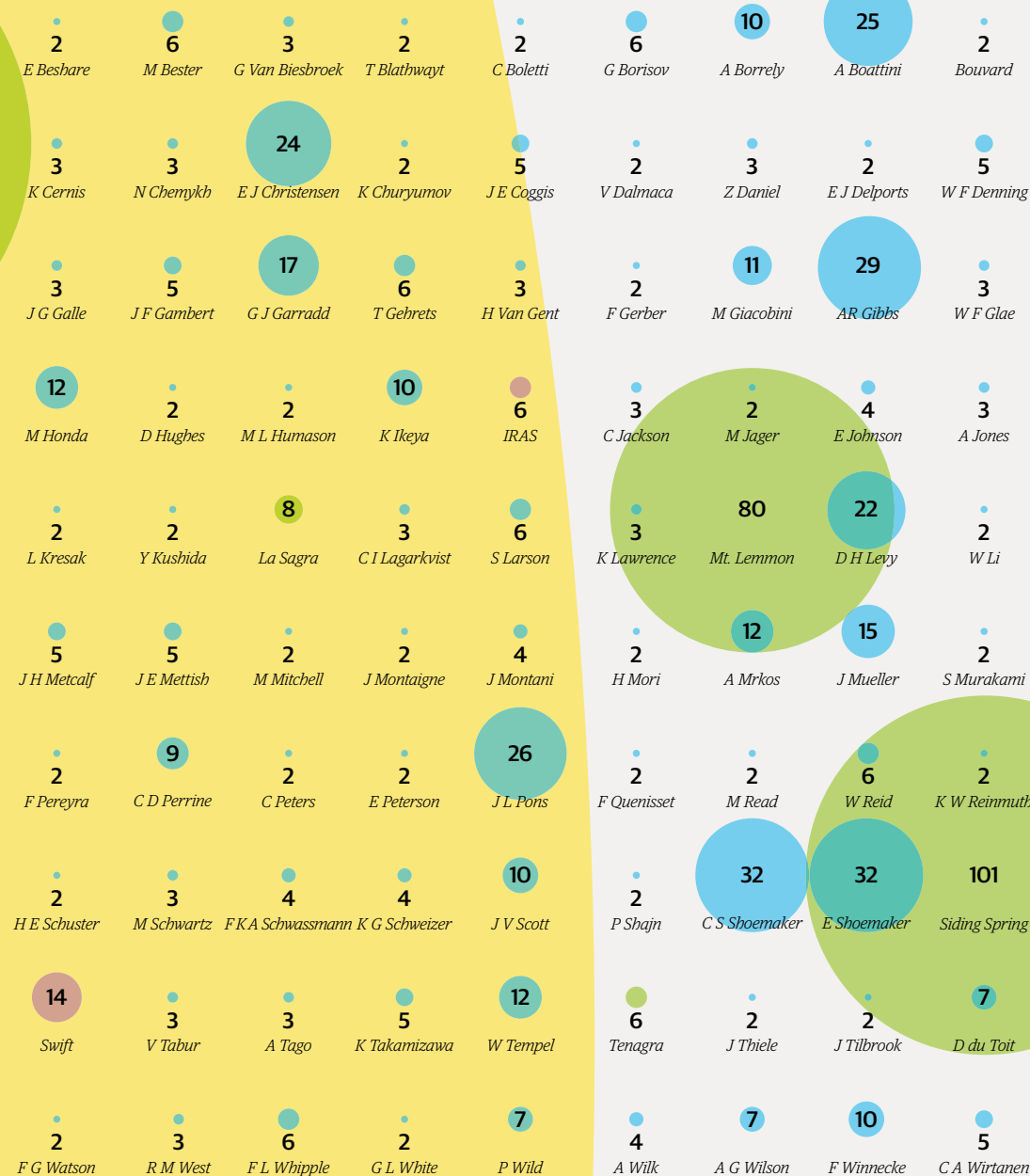
As telescopes became better they provided the ability to find comets without them having to be visible to the naked eye. One of the first astronomers to seriously search for them was Caroline Herschel, and between 1786 and 1797



she discovered eight comets. However, the most prolific comet hunter until this century was Jean-Louis Pons; working between 1801 and 1827 he discovered 37 comets. Anglo-Australian astronomer Robert McNaught, who has 82 comets to his name, only beat this record for an individual in 2000.

Robotic sky survey telescopes and spacecraft, as part of programmes to track and record objects that could present a threat to Earth, have also found many comets. Ground-based observatories like the Lincoln Near-Earth Asteroid Research (LINEAR), Catalina Sky Survey (CSS), and Pan-STARRS are scouring the sky with automated telescopes looking for tiny points of light moving against the background starfield. Although more diffuse comets (famously described as dirty snowballs) present less of a risk than dense asteroids, they could still have world-changing effects

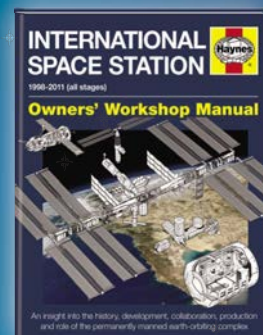
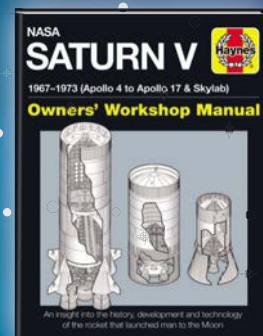
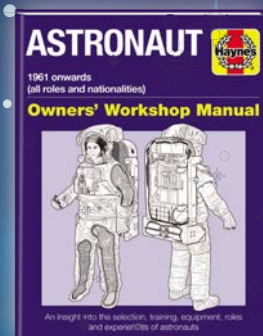
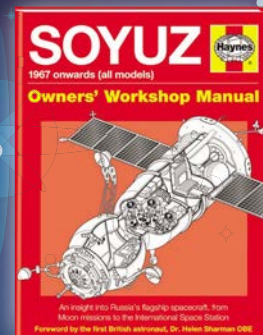
and are tracked among these efforts. Covering all near-Earth object classes, LINEAR has made 2,620 discoveries, CSS 7,038 and Pan-STARRS 3,050. But for comets in particular, the record holder is in space and actually studying the Sun. The Solar and Heliospheric Observatory (SOHO) is a joint ESA/NASA mission launched in 1995; it orbits the Sun-Earth Lagrange point L1, a position of gravitational balance between the Earth and the Sun. Its original two-year mission has been successfully extended for more than 20 years and it continues to observe the Sun and provide space weather data. A spin-off of the way the Large Angle and Spectrometric Coronagraph (LASCO) instrument blocks the solar disc to study the Sun's atmosphere has meant that SOHO has now discovered roughly half of all known comets, catching them as they dip in close to the Sun.



Human astronomers SOHO spacecraft
Automated sky surveys Spacecraft observatories



A WORLD OF INFORMATION



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DISCOVERED



Haynes
shows you how





STARGAZER

GUIDES AND ADVICE TO GET STARTED IN AMATEUR ASTRONOMY

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2

MAR



Conjunction between the Moon and Eris at a separation of $8^{\circ}41'$ in Pisces & Cetus

2

MAR



Conjunction of the Moon and Ceres at a separation of $0^{\circ}50'$ in Cetus

3

MAR



Asteroid 29 Amphitrite reaches opposition in Leo at magnitude +8.9

12

MAR



Comet 73P/Schwassmann-Wachmann reaches its brightest at magnitude +12 in Capricornus



14

MAR



Conjunction of the Moon and Makemake in Virgo & Coma Berenices

16

MAR



Conjunction of Venus and Mercury at a separation of $9^{\circ}32'$ in Pisces

20

MAR

MARCH EQUINOX

Spring begins in the Northern Hemisphere, while autumn starts in the Southern Hemisphere

20

MAR



The Moon and Saturn pass closely and within $3^{\circ}25'$ of each other in Sagittarius

23

MAR



Dwarf planet Makemake reaches opposition in Coma Berenices at magnitude +16.9

27

MAR



Mercury and Uranus make an approach, passing within $2^{\circ}24'$ of each other in Pisces

27

MAR



Conjunction of the Moon and Venus at a separation of $11^{\circ}19'$ in Pisces

Red light friendly

In order to preserve your night vision, you should read our observing guide under red light



www.spaceanswers.com



Jargon buster

Conjunction

A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)

This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude

An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition

When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

4
MAR



Conjunction of Mercury and Neptune at a separation of $1^{\circ}07'$ in Aquarius

6
MAR



Conjunction of Mars and Eris at a separation of $13^{\circ}11'$ in Pisces & Cetus

14
MAR



The Moon and Jupiter pass closely and within $2^{\circ}19'$ of each other in Virgo

15
MAR



Conjunction of the Moon and Haumea at a separation of $25^{\circ}28'$ in Virgo & Boötes

22
MAR



Conjunction of Moon and Pluto at a separation of $2^{\circ}43'$ in Sagittarius

23
MAR



Mercury hits its greatest brightness in the evening sky at magnitude -2.7

Naked eye

Binoculars

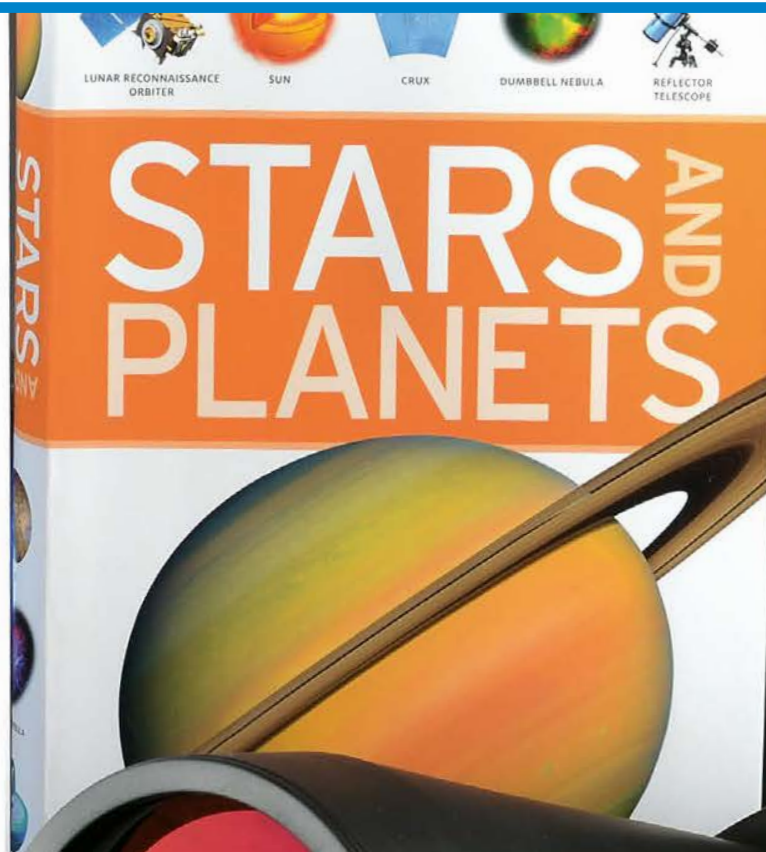
Small telescope

Medium telescope

Large telescope



© Vinish K Saini





How to beat **LIGHT POLLUTION** *tonight*

Thought it was impossible to observe the wonders of the night sky from towns and cities? Think again! Follow our tips and tricks on successfully observing through sky glow

Written by Jaspal Chadha

Light pollution and astronomy don't go hand in hand. If you're a resident of a town or city, this may be a statement that has put you off from buying a telescope or simply heading outside to gaze up at the night sky. It's true that there's no contest between a dark sky site and a city brimming with life and streetlights: an area completely untouched by an orange artificial haze will win hands down. On the flip side of the coin though, it's not

impossible for successful views of the night sky to be had from towns and cities. That is, provided you have a little bit of know-how in cheating your way to better observing conditions. Unsure of where to start in the quest to beat light pollution? **All About Space** provides the ultimate tips and tricks for getting the very best sights of your favourite targets from less than ideal skies, whatever the intensity of artificial light in your area.



Use a red torch

An obvious one, but it's essential that you use a red torch when reading your sky atlas and finding your way around. Red light doesn't ruin your night vision, ensuring that your pupils are fully dilated to receive light from distant objects.



Check the weather

Wait for stable conditions and low wind speeds. High humidity or prolonged dry spells where dust is thrown up into the atmosphere will make observing conditions worse.



Cover yourself

Use a dark cloth to cover your head and eyepiece to shield them from stray light. This method is surprisingly effective in getting your eyes dark adapted, allowing the pupil to dilate as fully as possible.



Get the best views in light-polluted areas

Even from areas plagued by an artificial haze, astronomers can still enjoy an impressive array of night-sky objects. Here's how...

Light pollution is usually no match for the Moon and the brighter naked-eye planets, which can still be observed with great success from light-polluted areas. The Moon is a great target to observe not just for those who live in towns and cities but also those who are just breaking into the hobby of astronomy - there's plenty to explore on its rugged surface and especially as it changes from one phase to the next, serving as an incentive to explore the universe from less than ideal conditions. If you're looking to observe further into deep space, taking in splendid sights of star clusters, nebulae and galaxies, then it's best to wait until a Moonless night to avoid adding more interference.

It may come as no surprise that the best place to point your telescope is straight upwards, or what is usually referred to as past the zenith - it's here that you'll be looking through less pollution and atmosphere compared to looking along the horizon. Use planetarium software or the internet

to find out which objects are at their highest point, as this will ensure improved detail of the more diffuse objects like galaxies and nebulae. Imaging will provide even more clarity if you combine monochrome narrowband images with those that have been shot using oxygen and sulphur filters.

If you're keen to observe into the small hours, you'll notice that after midnight there will be much less stray light - a result of those heading to bed and turning outside lighting off. You may also find that some local authorities dim street lamps or turn them off during the night. If this isn't the case in your area, you can shield yourself from stray light by heading into shadow or covering your optics by putting a blanket over your head when looking through your eyepiece. Extending your dew shield by using thick black card also works wonders. If you're using binoculars then 'flexible wings' will be useful in navigating targets with reduced interference.



Keep your optics clean

Clean and collimate all optics on your instrument. Optics that are covered in dirt and grease scatter light, giving you bad views of your target.



Use a branded filter

Filters (such as O-III) are good for planetary and emission nebulae. Stay away from the cheap ones that you can usually find on eBay and invest in those that promote high



Look directly above

Try to catch your target objects straight overhead – this is always the darkest part of the sky, where you're looking through less smog and atmosphere.

Know your observing conditions

Bortle Scale:

9

Inner-city sky

The Milky Way is not visible, while the Pleiades Cluster (M45) is invisible to all but the most experienced. Only constellations with bright stars are visible and they are missing fainter stars. Clouds are brilliantly lit.

Faintest magnitude: 4.0 *

Bortle Scale:

7

Suburban/urban sky

Our galaxy is almost invisible and objects such as the Andromeda Galaxy and the Beehive Cluster are difficult to see. The constellations with brighter stars are easily recognisable, while clouds are brilliantly lit by airglow.

Faintest magnitude: 4.6-5.0

Bortle Scale:

5

Suburban sky

The Milky Way appears washed out overhead and is lost near the horizon. The Andromeda Galaxy is detectable, as is the glow of Orion Nebula. There are only slight hints of zodiacal light during spring and autumn.

Faintest magnitude: 5.6-6.0

Bortle Scale:

3

Rural sky

The Milky Way is complex, with dark and bright patches, and an outline is visible. In spring and autumn, zodiacal light is striking, extending 60 degrees above the horizon. Bright globular clusters are distinct and M31 is visible.

Faintest magnitude: 6.6-7.0

Bortle Scale:

1

Excellent dark sky

The Milky Way shows great detail and light from the Scorpio-Sagittarius region casts shadows on the ground. Zodiacal light stretches across the sky. Bluish airglow is visible near the horizon and clouds appear as dark blobs.

Faintest magnitude: 7.6-8.0

Sky Quality
Meter reading:

<18.38

Sky Quality
Meter reading:

19.99-18.38

Sky Quality
Meter reading:

20.99-20.00

Sky Quality
Meter reading:

21.74-21.00

Sky Quality
Meter reading:

22.00-21.75

Bortle scale

Consisting of a nine-level numeric scale, the Bortle scale – named after astronomer John Bortle – measures the night sky's brightness in a location, quantifying the observability of an object and the interference caused by light pollution. Bortle scale 1 relates to an excellent dark sky site, while scale 9 relates to an inner city sky.

Sky Quality Meter: measuring your sky

These handheld devices – which are produced by and purchased from Canadian company, Unihedron – are capable of measuring the luminance of the night sky at your location. Measurements at 21.75 magnitudes per square arcsecond or above represent brilliant night sky views.



Your targets for tonight

Get under the stars and push your eyes, binoculars and telescope to the limit under light-polluted skies - you'll be amazed at what you can see



Choose your target carefully

Select the right objects to observe and don't get too hung up on magnitude. A bright galaxy with a decent brightness may be invisible since it's diffuse, while a dim planetary target that's not diffuse may be much easier to spot.



Observe after rain

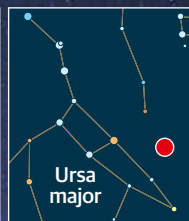
After a shower, night skies appear darker as light is no longer reflected off dust particles in the air. It's a small advantage when observing in light-polluted areas but can certainly help with observations.



Bode's Galaxy (M81)

Constellation: Ursa Major
Magnitude: 6.9

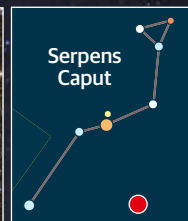
M81 is one of the easiest and most rewarding galaxies to observe in the Northern Hemisphere, as it can be found with small instruments.



Messier 5

Constellation: Serpens
Magnitude: 5.6

This globular cluster, found quite easily with a sweep of your binoculars, contains about 150,000 stars within a diameter of 150 light years.



Messier 52

Constellation: Cassiopeia
Magnitude: 7.3

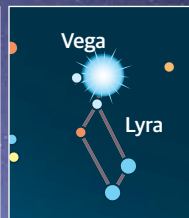
M52 is estimated to be 35-50 million years old. This is a relatively young star cluster and complements very well in a wide-field shot with the Bubble Nebula.



Vega

Constellation: Lyra
Magnitude: 0.03

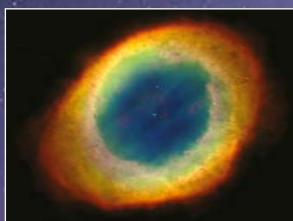
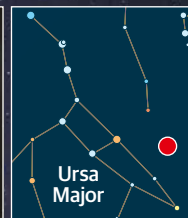
Vega, also called Alpha Lyrae, is the brightest star in the Northern Hemisphere constellation Lyra and is fifth brightest in the night sky.



Cigar Galaxy (M82)

Constellation: Ursa Major
Magnitude: 8.4

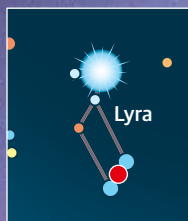
Forming a conspicuous pair with its neighbour, M82 resembles a cigar, which gives it its name. From most conditions you'll need a telescope to see it.



Ring Nebula (M57)

Constellation: Lyra
Magnitude: 8.8

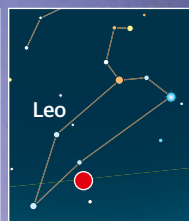
This planetary nebula, which is the result of a red giant puffing off its outer layers, is a breeze to locate as it is positioned between Beta and Gamma Lyrae.



Leo Triplet

Constellation: Leo
Magnitude: 10.25

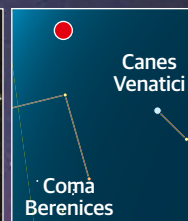
The group consists of the galaxies M65, M66 and NGC 3628. The Leo Triplet lies at an approximate distance of 35 million light years from Earth.



Messier 3

Constellation: Canes Venatici
Magnitude: 6.2

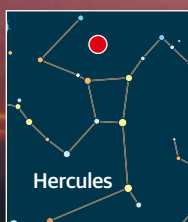
M3 is one of the most outstanding globular clusters, containing an estimated 500,000 stars. It is famous for the large number of variable stars discovered in it.



Messier 92

Constellation: Hercules
Magnitude: 6.4

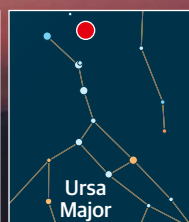
M92 is a more conspicuous globular cluster. Situated in the constellation Hercules, it is second only in brightness within that constellation, after bright M13.



The Pinwheel Galaxy (M101)

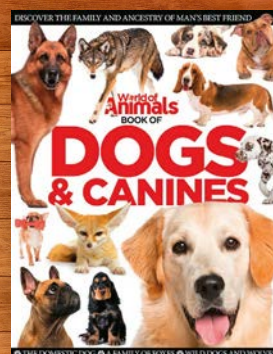
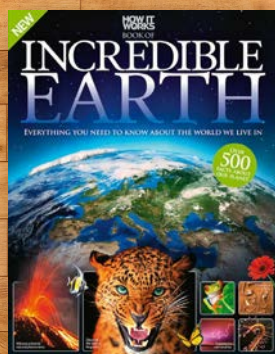
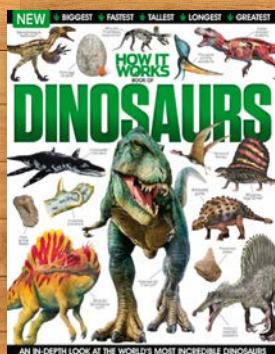
Constellation: Ursa Major
Magnitude: 7.9

M101 is revealed as one of the most prominent 'Grand Design' spirals in the sky. This face-on spiral is a large galaxy that's even wider than our Milky Way.



Shade your optics

If you're finding it hard to shield yourself from any stray light, then you should attempt to shield the optics you are using. Short dew shields can be extended using thick, black (or dark-coloured) card, and telescope and binocular eyepieces can be shielded using flexible wings.



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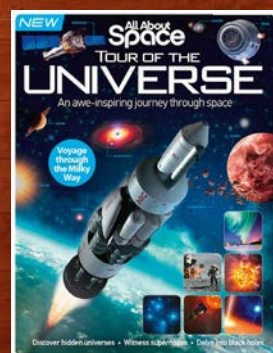
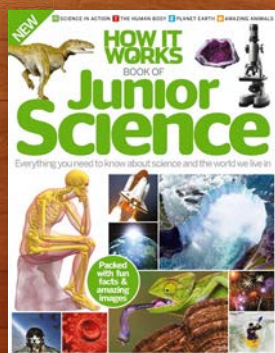
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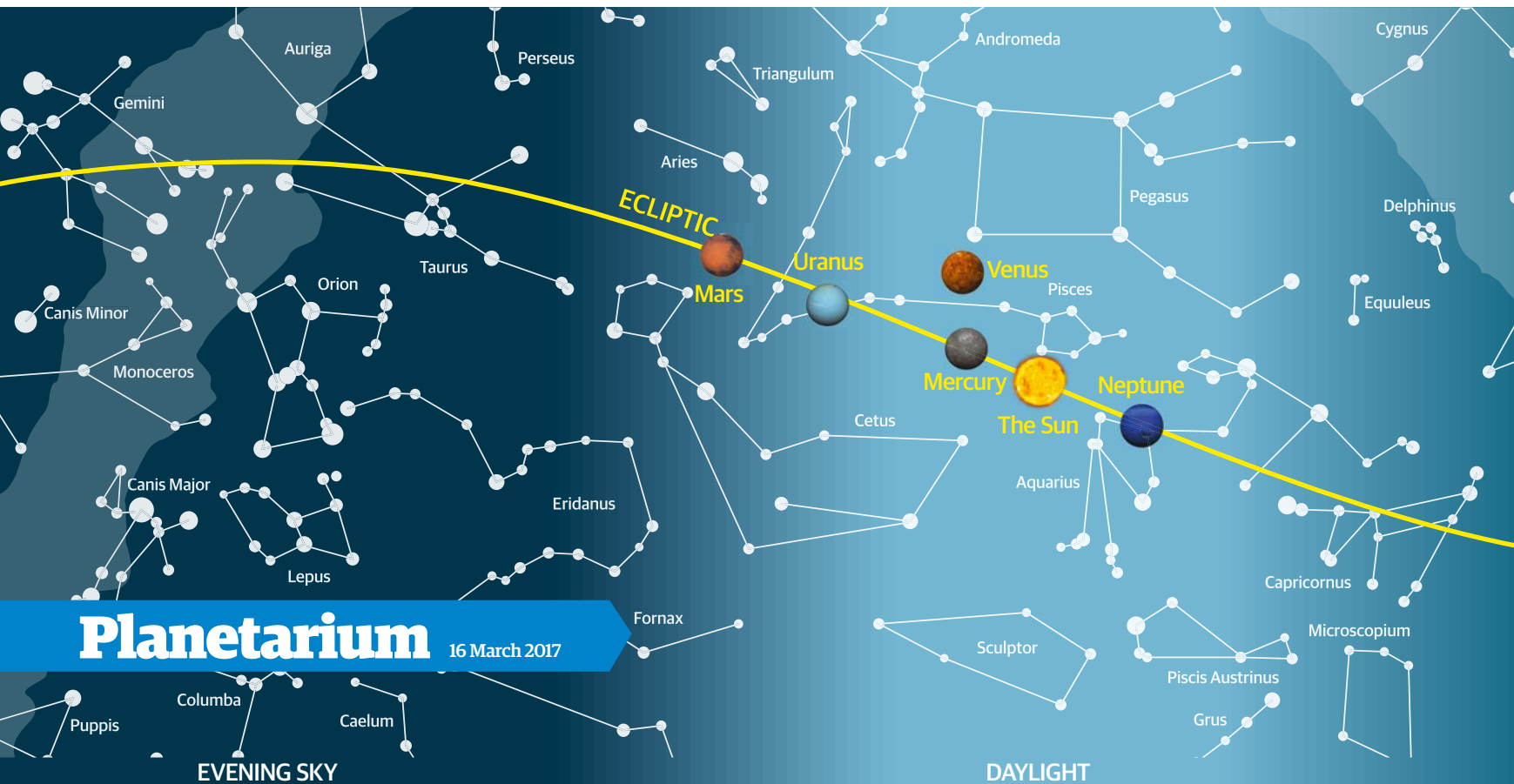
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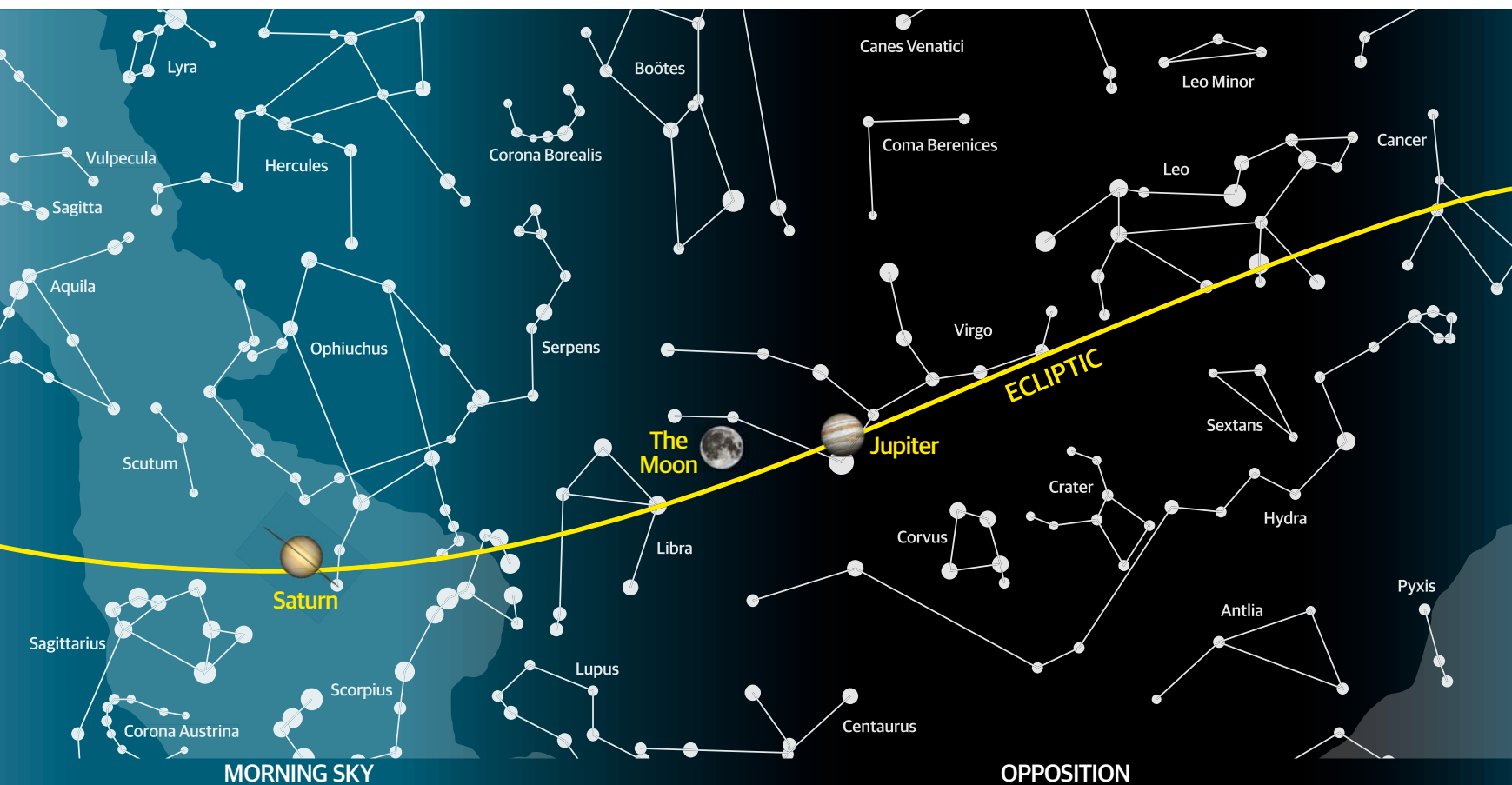
Moon phases

Moon phases

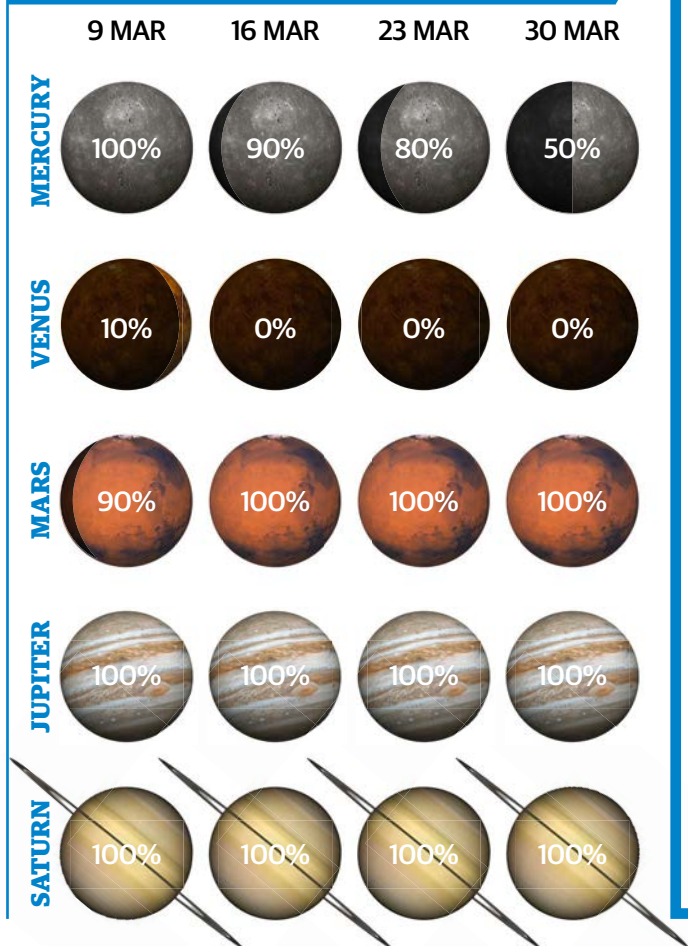
							2 MAR 19.7% 8:42 22:39	3 MAR 30.0% 09:13 23:55	4 MAR 41.5% 09:49 ---	5 MAR FQ 53.4% 01:08 10:30
6 MAR 65.0% 02:16 11:20	7 MAR 75.6% 03:16 12:16	8 MAR 84.8% 04:08 13:20	9 MAR 92.0% 04:52 14:28	10 MAR 97.0% 05:28 15:38	11 MAR 99.6% 06:00 16:49	12 MAR FM 99.9% 06:27 17:59				
13 MAR 99.8% 06:52 19:07	14 MAR 97.8% 07:15 20:13	15 MAR 93.8% 07:39 21:19	16 MAR 88.1% 08:04 22:22	17 MAR 81.0% 08:31 23:24	18 MAR 72.8% 09:01 ---	19 MAR 63.8% 00:23 09:36				
20 MAR LQ 54.2% 01:19 10:16	21 MAR 44.3% 02:11 11:03	22 MAR 34.5% 02:57 11:56	23 MAR 25.0% 03:39 12:56	24 MAR 16.4% 04:15 14:02	25 MAR 9.1% 04:48 15:12	26 MAR 3.7% 06:18 17:26	Clocks go forward 1 hour			
27 MAR 0.6% 06:46 18:42	28 MAR NM 0.3% 07:13 20:01	29 MAR 3.0% 07:42 21:20	30 MAR 8.6% 08:13 22:39	% Illumination 🕒 Moonrise time 🌑 Moonset time			FM Full Moon NM New Moon FQ First quarter LQ Last quarter			

All figures are given for 00h at midnight (local times for London, UK)

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage



Planet positions

All rise and set times are given in GMT

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	2 Mar	22h 37m 58s	-10° 48' 10"	Aquarius	-1.9	06:48	17:04
	9 Mar	23h 26m 22s	-05° 15' 14"	Aquarius	-2.2	06:40	17:54
	16 Mar	00h 15m 21s	+01° 05' 20"	Pisces	-2.5	06:29	18:47
	23 Mar	01h 02m 08s	+07° 30' 24"	Pisces	-2.7	06:15	19:39
	30 Mar	01h 40m 04s	+12° 44' 18"	Pisces	-2.5	06:58	21:18
VENUS	2 Mar	00h 36m 41s	+11° 05' 19"	Pisces	-5.3	06:54	20:55
	9 Mar	00h 33m 43s	+11° 56' 51"	Pisces	-5.0	06:18	20:30
	16 Mar	00h 23m 52s	+11° 40' 44"	Pisces	-4.3	05:43	19:51
	23 Mar	00h 09m 21s	+10° 13' 03"	Pisces	-3.1	05:08	19:01
	30 Mar	23h 54m 33s	+07° 53' 43"	Pisces	-3.3	05:38	19:06
MARS	2 Mar	01h 28m 38s	+09° 19' 31"	Pisces	1.0	07:55	21:38
	9 Mar	01h 47m 45s	+11° 14' 41"	Aries	1.0	07:36	21:40
	16 Mar	02h 07m 00s	+13° 04' 19"	Aries	1.1	07:18	21:41
	23 Mar	02h 26m 23s	+14° 47' 42"	Aries	1.2	07:00	21:43
	30 Mar	02h 45m 56s	+16° 24' 13"	Aries	1.2	07:42	22:44
JUPITER	2 Mar	13h 23m 44s	-07° 10' 10"	Virgo	-2.3	21:12	08:11
	9 Mar	13h 21m 38s	-06° 56' 16"	Virgo	-2.4	20:41	07:42
	16 Mar	13h 19m 06s	-06° 39' 56"	Virgo	-2.4	20:10	07:14
	23 Mar	13h 16m 13s	-06° 21' 39"	Virgo	-2.4	19:38	06:45
	30 Mar	13h 13m 04s	-06° 01' 59"	Virgo	-2.4	20:06	07:16
SATURN	2 Mar	17h 45m 06s	-22° 05' 08"	Sagittarius	1.1	03:02	11:06
	9 Mar	17h 46m 38s	-22° 05' 13"	Sagittarius	1.1	02:36	10:40
	16 Mar	17h 47m 51s	-22° 05' 09"	Sagittarius	1.1	02:10	10:14
	23 Mar	17h 48m 44s	-22° 04' 56"	Sagittarius	1.0	01:43	09:47
	30 Mar	17h 49m 16s	-22° 04' 36"	Sagittarius	1.0	02:16	10:20



This month's planets

After sunset, the evening skies of spring are brimming with planets for astronomers to observe with the naked eye, binoculars and telescopes

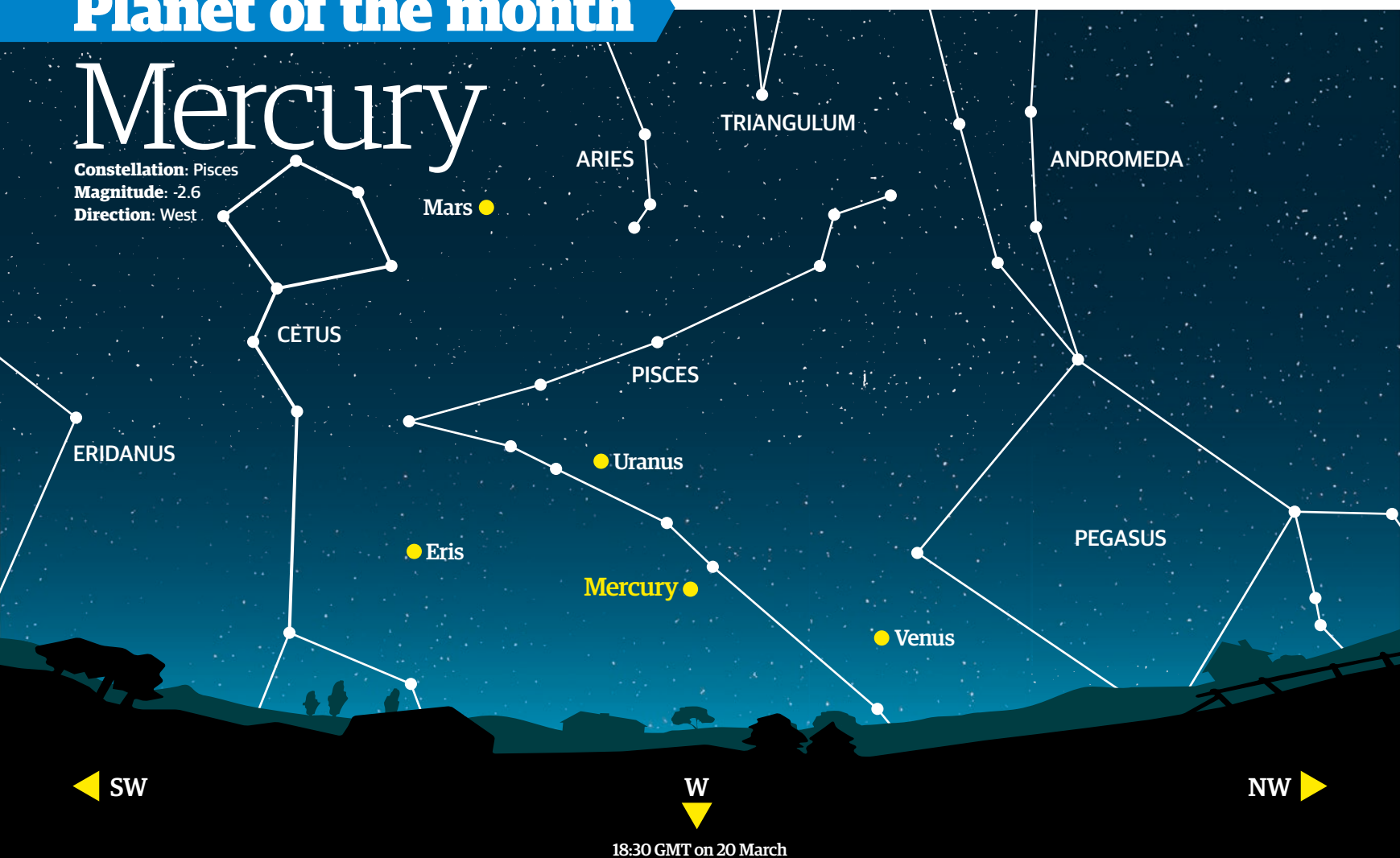
Planet of the month

Mercury

Constellation: Pisces

Magnitude: -2.6

Direction: West



18:30 GMT on 20 March

Mercury is a small world, just 4,879 kilometres (3,032 miles) across, which whips around the Sun once every 88 days - fitting for a planet named after the winged messenger of the gods. Because Mercury orbits so close to the Sun - on average it is just 58 million kilometres (36 million miles) from the Sun, which is less than half as far away from our star as the Earth is - it can only ever be seen close to the Sun in the sky, for a short period after sunset, or a short period before sunrise. This has led to Mercury earning a reputation as being hard to see, but if you look for it at the right time, and from the right place (somewhere out in the open, with no obstructions on the horizon), it's actually quite easy to track down and a surprisingly obvious naked-eye object.

Even though it only becomes visible towards the end of March, Mercury is our 'Planet of the Month' this issue because it will make a big impression when it eventually appears. We'll first spot it around the 20 March, very low in the west after sunset, ten degrees to the left of far, far brighter Venus. To pin it down, find Venus as soon after sunset as you can and then look a little way to its left for a fainter, more copper-hued 'star'. If you can't see Mercury with your naked eye, either wait a while for the sky to get darker or use your binoculars to sweep the sky to Venus' left until Mercury pops into view. Once you've found it you'll find it quite easy to go back to.

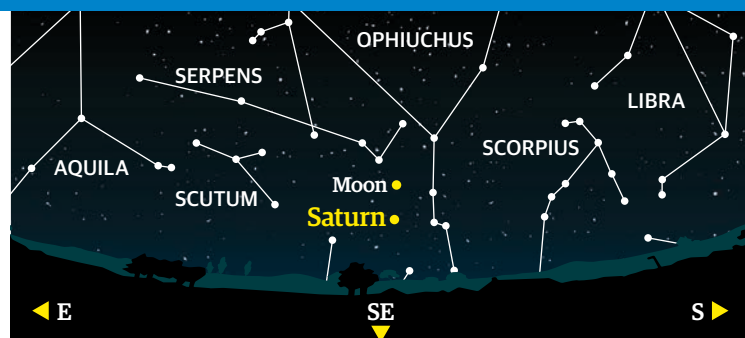
As the last days of March pass, Mercury will speed up and away from Venus, heading towards Mars and

passing much fainter Uranus along the way. Over the 25-26 March you'll be able to see Mercury and Uranus side by side in binoculars or a small telescope, barely two degrees apart. Then the two worlds will pull apart, leaving Mercury to shine on its own at a very respectable magnitude of -2.5 on the last evening of the month, looking like an obvious naked eye "star" that doesn't set until almost two hours after the Sun.

Cross your fingers for clear skies on 30 March as Mercury will be centre stage in a celestial line up in the evening twilight. After sunset the crescent Moon, with "Earthshine", will shine to the lower left of Mars and to their lower right will be Mercury. Together the three objects will make a very attractive triangle as dusk deepens - definitely worth trying to photograph!



Saturn 03:00 GMT on 20 March



Constellation: Sagittarius

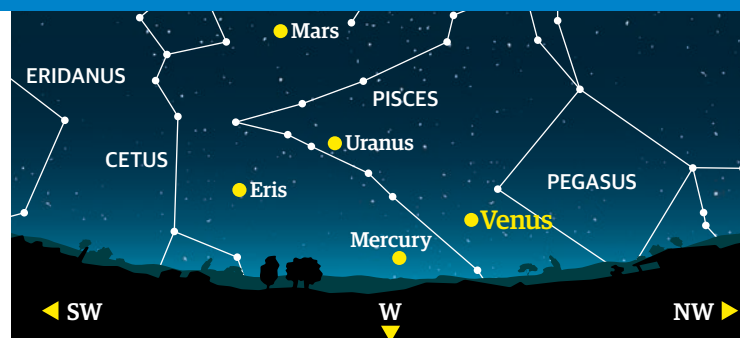
Magnitude: 1.1

Direction: Southeast

Saturn is a morning star in March, rising at 3.30am at the start of the month and only an hour earlier as it ends. Saturn looks like a yellow-

white star near the western border of Sagittarius, to the upper right of the famous Lagoon Nebula. At magnitude 1.1, it is a naked-eye object but strikingly fainter than Jupiter. Through a telescope Saturn looks amazing - its rings are wide open.

Venus 18:45 GMT on 17 March



Constellation: Pisces

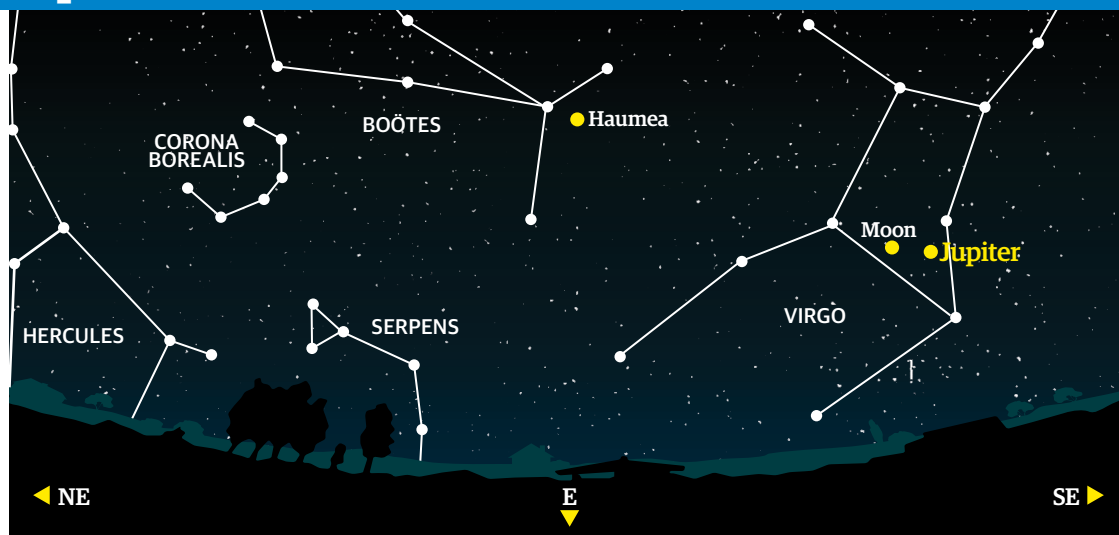
Magnitude: -4.1

Direction: West

In early March Venus will look like a tiny crescent through a telescope or powerful binoculars, shining to the lower right of Mars and Uranus.

As the days pass, Venus heads towards the Sun. Between the 17-20 March, Venus will appear to slide past Mercury as that planet emerges from the Sun's glare, climbing in the western sky. By the end of March we lose Venus from the evening sky.

Jupiter 22:00 GMT on 14 March



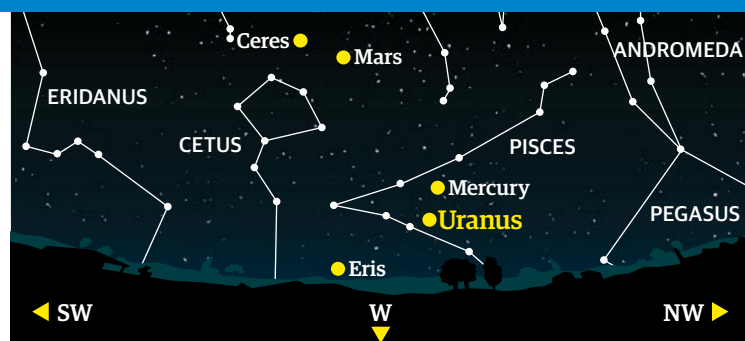
Constellation: Virgo

Magnitude: -2.4

Direction: East

Jupiter is now an evening object, rising before 10pm, remaining visible all through the night and high in the south at 3am. Shining at magnitude -2.3, there is nothing else as bright as Jupiter in that part of the sky, so it is impossible to miss it. Jupiter spends the month shining above Virgo's brightest star, Spica, but is so much brighter than the star its glare almost overwhelms it. On 13 March an almost-full Moon will be to Jupiter's upper right and as they rise together at around 9pm, they will be a striking sight to the naked eye. On the following evening they will look even more impressive as the Moon glows less than two degrees to Jupiter's upper left.

Uranus 20:00 BST on 27 March



Constellation: Pisces

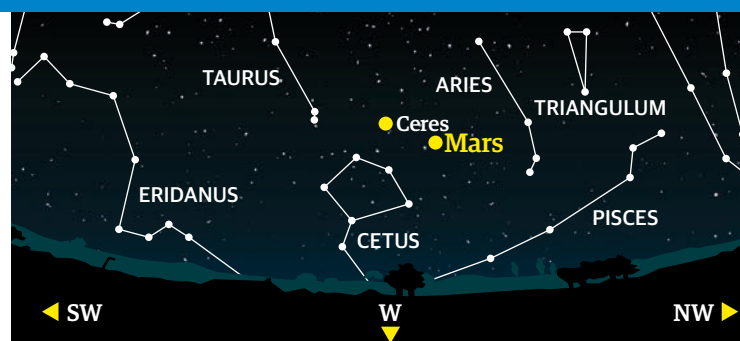
Magnitude: 5.9

Direction: West

Shining at magnitude 5.9, Uranus is a naked-eye object but unless you know the constellation of Pisces very well, you won't be able to tell which

'star' is the planet. Binoculars hint at its pale green colour but a telescope is needed to resolve its tiny disc. In early March Uranus is just 2.5 degrees away from Mars, below and to the right, but by the month's end the two worlds will have drifted apart.

Mars 20:00 GMT on 25 March



Constellation: Aries

Magnitude: 1.2

Direction: West

Mars is little more than an unremarkable orange "star" shining in the west after sunset during March. Through binoculars its colour and

brightness are slightly enhanced but it is now so far away it is a tiny orange disc - less than five arcseconds across - in a telescope. We'll have to wait until later in the year for its size and brightness to increase, and for surface features to become visible.



Moon tour

Endymion crater

Get to know one of the Moon's lesser known impact features

Top tip!

In early March, Endymion is tilted almost as far towards us as it ever gets, making it a great time to turn your binoculars or telescope skyward.

Several of the Moon's impact features are so large they are visible to the naked eye. Round Mare Serenitatis, which forms the left eye of the 'man in the Moon', is the most obvious, followed by Mare Imbrium and bright young craters such as Copernicus, Tycho and Aristarchus. But scattered here and there are smaller, less obvious features, bigger than the average craters but smaller than the great lava-filled seas, which are worth hunting down when the phase is right. One of these is Endymion, a small, roughly circular crater found near the very "top" of the Moon.

Endymion's mythological roots are rather confused. Depending on which account you read, the crater was named after either a shepherd or a king. However, most stories agree that Endymion was so handsome and dreamy that Selene, the Titan goddess of the Moon, became so besotted with him that she begged Zeus to put him into an eternal sleep so he would never age and she could drool over him forever.

If Endymion was farther away from the limb we would be able to

see its true round shape, and it would look not unlike Ptolemaeus, or even a slightly lighter version of Plato, but its close proximity to the edge of the Moon means that our view is greatly foreshortened. On the plus side, its location there means that sometimes we can see it more clearly than others, thanks to the lunar libration, or its slight wobbling, which swings features close to (or even around) the limb into view. At the start of this month, Endymion is tilted almost as far towards us as it ever gets, so this is a great time to look for it.

Through a small telescope Endymion looks like little more than a dark, oval spot, high above Mare Crisium, almost at the Moon's limb. Larger telescopes reveal it to be a crater with a classic dark, flat floor. Images taken by lunar orbiters show the "flat" floor is peppered with countless tiny craters, as if blasted by a shotgun, but they're so small it's unlikely you'll see them through your telescope. Up towards the top of the crater, you'll see the "Endymion Triplet", a trio of craters arranged in a short line on the floor, pointing towards the crater's

centre. They remind many observers of a mirror image of Orion's Belt.

Studies by lunar orbiters and ground-based observers show that Endymion is 122 kilometres (75.8 miles) across and 4.9 kilometres (3 miles) deep. Even from 384,400 kilometres (238,850 miles) away we can see that its walls are quite steep, and they can look very dramatic under the right conditions, when the crater is close to the terminator. Under high magnifications you'll see its far walls are terraced and slump in places.

As March begins, and a beautiful crescent Moon hangs low in the west after sunset, Endymion is already fully illuminated, the terminator - the line between night and day - having swept over it on 28 February. By the time the Moon reaches first quarter on 5 March, Endymion is losing definition, as the Sun's rays fall on it almost from overhead, shrinking the shadows cast by its walls. By full Moon on the 12 March, the crater is reduced to a mere dull grey oval near the top of the lunar disc. But just a day later the terminator will be creeping towards it again, and

its walls will be hit by more slanting rays of sunlight, briefly bringing them back into view for a mere day or so before the terminator rolls over the crater and plunges it into darkness again. Endymion will be hidden from view until 30 March, when dawn breaks over the crater's walls and it reappears.

So, this month, try to drag your eyes away from your favourite lunar features and track down Endymion. It might not be the most dramatic or attractive feature on the Moon, but once you've seen it you'll keep going back to it.



This month's naked eye targets

Take a tour of Leo (The Lion), Cancer (The Crab) and Gemini (The Twins) this evening, without the need of a telescope

Castor and Pollux

These two bright stars mark the heads of Gemini (The Twins). Pollux, a giant star with an orange hue, is the brighter of the two stars at a magnitude of +1.14. Castor, which glows at a magnitude of +1.57 and with a blue-white colour, is a multiple star system - you'll need at least a small telescope to resolve these stars. Castor and Pollux are visible in the same field of view with a pair of 10x50 binoculars.

Gemini

Lynx

The Beehive Cluster (M44)

Looking like a fuzzy patch of light to the naked eye, binoculars with a magnification of at least 10x50 show this lovely star cluster in all its glory. Also known as Praesepe, Messier 44 fits well in the field of view of a pair of binoculars and contains red giants, white dwarfs and stars similar to our Sun. Its blue-white members are the most obvious when viewed by the unaided eye alone.

Cancer

The Sickle (asterism)

This group of stars, looking like a backward question mark, is the head and mane of Leo the Lion and is a sign that spring is here. The Sickle contains the blue-white star Regulus, orange Algeba and yellow Adhafera.

Messier 67

One of the oldest known open clusters, Messier 67 contains more than 100 stars that are similar to the Sun, along with numerous red giants. Messier 67 is nicknamed the King Cobra Cluster and appears the same size as the full Moon. Through a small pair of binoculars, you should be able to see an elongated patch of light.

Regulus

The brightest star in Leo, Regulus is 79 light years away and is a multiple star system. Regulus marks the bottom of 'The Sickle' - an asterism which makes up the Lion's mane. Regulus is one of the brightest stars in the sky, shining with a white-blue hue at a magnitude of +1.4.

Leo

Hydra

How to...

Catch the colours of the Wishing Well Cluster

Located in the constellation of Carina, NGC 3532 is packed full of colourful stars

You'll need:

- ✓ Binoculars
- ✓ A telescope
- ✓ Tracking mount
- ✓ DSLR camera
- ✓ Camera adaptor
- ✓ Remote shutter release

Catalogued as NGC 3532, the Wishing Well Cluster is an open star cluster and contains about 400 stars; some are red in colour and others orange, white or blue. It is a bright cluster and easily seen with the naked eye, found in the constellation of Carina, not far from the famous Eta Carina Nebula and northwest of the Southern Cross, in the misty river of light, the Milky Way. It is thought that the cluster is around 300 million years old and covers an

area of sky almost twice the size of the full Moon. The stars do indeed seem to glitter like coins at the bottom of a wishing well.

Nicolas Lacaille first catalogued the cluster in 1752 and John Herschel said it was one of the finest clusters in the night sky. He also observed many double stars in the group. It contains several red giant stars - large stars many times the mass of the Sun, which have used up their fuel very quickly and have expanded as they reach the end of their lives - as well as blue stars, which are of moderate mass but very hot, and white dwarf stars, which are the remnants of stars that have used up nearly all their fuel and have collapsed to small, very dense objects.

Binoculars will show the cluster well and a small telescope will resolve the stars even better. The larger the aperture of your telescope, the brighter and more distinctive the colours of the

stars will seem. Associated with this star cluster is gas and dust that shows up as red and blue in long-exposure photographs. The red gas glows by absorbing light energy from nearby stars and re-emitting it at a frequency that appears red, while the blue colour is caused by light from nearby stars reflecting off the dust.

To show the colours really well requires long-exposure images, which can be achieved by taking a series of shorter exposures and stacking them together in image processing software. You can use a DSLR camera or specialist astronomical imaging camera coupled to a telescope, and the more images you take the better, as you are more likely to be able to saturate the colours during processing to get really good results. Make sure your telescope mount is well polar aligned, too, to keep the star images small and crisp.

Tips & tricks

Locate the cluster with a pair of binoculars

You can easily see the cluster in 7x50 or 10x50 binoculars, although the colours of the stars will seem subdued.

Follow up with a telescope

A small telescope will resolve the stars in the cluster well. Larger apertures will seem to intensify the colours.

Get a tracking mount

If you intend to take images of the cluster, you'll need a polar aligned equatorial tracking mount.

Use a DSLR camera

A DSLR camera attached to your telescope should start to show the colours of the stars in the cluster well.

More is better!

Take lots of exposures of the same length, as these can be stacked in software to improve detail and contrast.



Imaging colourful stars

Taking plenty of shots is the best way to show up the differing stellar hues

Set the camera to 'manual' and the ISO value to 800 or 1,000, which will allow good sensitivity of the imaging chip without too much noise. Take 30-second exposures and make sure the shots are of the same duration. Also take several shots, at least

seven, say, with the telescope capped and for the same duration. These are dark frames and will be used to remove any electronic 'noise' in your images. Use software such as Deep Sky Stacker (free on the internet) and/or Photoshop to process the images.

Send your photos to
space@spaceanswers.com



1 Attach the camera

Fix your DSLR camera to your telescope using a T-Ring adaptor. Make sure that it is secure and the telescope is sturdy.



2 Adjust the settings

Using the 'manual' mode on your camera set the ISO value to 800 or 1,000 and set the exposure length to 30 seconds.



3 Test your motor drive

It is important to make sure the telescope's drive is running smoothly and effectively before starting your exposures.



4 Centre the image

Using the camera's view screen, make sure the star cluster is centred in the field of view and that the image is framed nicely.



5 Take lots of shots

Take several exposures - the more the better! - but ensure they are all of the same duration. Once you have finished, take a few 'dark frames'.



6 Process your images

Process your images using software such as Deep Sky Stacker and Photoshop to get a final colourful image of the Wishing Well Cluster.



NGC 2903

Deep sky challenge

The Lion's galaxies

The evenings of early spring are welcomed by the arrival of deep-sky objects

Spring is known as the season of the galaxies to astronomers, as the night side of the Earth is facing away from the Milky Way and out into deep space, which is littered with other such 'island universes' as our own. The distances to these objects are truly vast and so we often see them as small, hazy patches of light, but these objects are anything but small. Like the Milky Way, they contain billions of stars, clusters and nebulae in their own right. They also come in various shapes and sizes and can be a little smaller or even a lot larger than our own galaxy. Due to line of sight effects as well as gravitational ones, they can also seem to occur in groups, such as the Leo Triplet, or they might just appear as isolated misty patches of light, floating in the depths of space.

1 NGC 2903

The spiral galaxy NGC 2903 is considered to be 'active' due to the high rate of star birth going on in its core. Observations using modest telescope apertures reveal a bright oval embedded in a haze. Good sky conditions will reveal its spiral arms.

2 Messier 95

Look through a telescope at Messier 95 and you'll see that it is a face-on spiral galaxy. Located 38 million light years away in the Lion's belly, Messier 95 is home to a supernova, which was discovered back in 2012.

3 Messier 96

Like M95, this galaxy has a spiral structure and can be found in the 'stomach' of Leo. It's said that M96 is of a similar size to the Milky Way at 100,000 light years across. Small telescopes reveal a very faint patch of light - the galaxy's oval core.

4 Messier 105

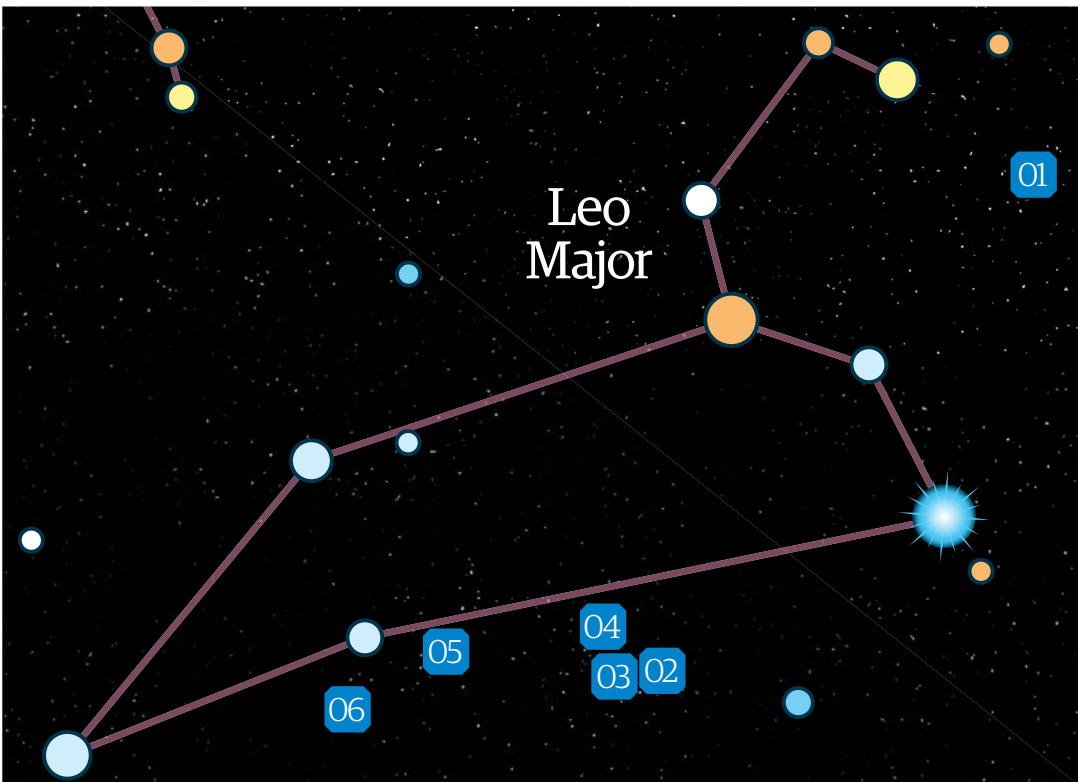
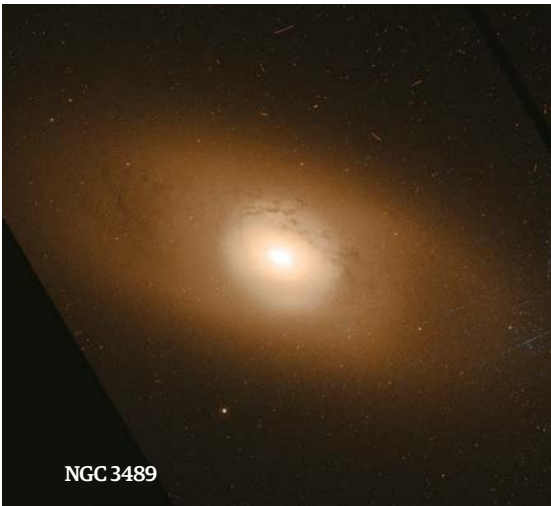
Being an elliptical galaxy, M105 doesn't have a great deal of detail, with even the largest telescopes showing it as a blob of light. Telescopes with apertures of at least 10" will reveal neighbouring NGC 3384 and NGC 3389 in the same field of view.

5 NGC 3489

Large aperture telescopes will reveal NGC 3489's bright and fuzzy core. This lenticular galaxy is 32 million light years away and, with a magnitude of +10.3, it is best viewed under very good observing conditions.

6 The Leo Triplet

Consisting of M65, M66 and NGC 3628, this famous group of galaxies is a popular target for those with not just a telescope, but those who like to dabble in astrophotography. These three large spiral galaxies can be viewed in the same field of view.





How to...

Make a sundial out of cheap materials

A fascinating instrument to both make and use, learn how to make one of these devices

You'll need:

- ✓ Stiff card
- ✓ Scissors
- ✓ Glue
- ✓ A printer
- ✓ Something with a blunt point
- ✓ Computer with internet access
- ✓ A PDF viewer

Sundials are as popular as they have ever been. You can see them in ornamental gardens, on the side of buildings and even in people's pockets. Sundials can be very simple or very ornate, however, they all do essentially the same thing, which is to cast a shadow from the Sun onto a marked scale from which you can read off the time. They have been

used for millennia and long before the invention of the clock; examples of sundials have been found in Ancient Egypt and Babylonia. The first sundial, as we would recognise it, is said to have been invented by Theodosius of Bithynia around 160-100 BCE.

There are a couple of things you need to do to make a sundial accurate. First of all, they have to be marked up accurately and the gnomon, or central pointer, which casts the shadow, needs to be set to your latitude. If you're planning to make a sundial from scratch, you'll also need to use the 'equation of time'. This can seem daunting at first, but it is possible to produce an accurate sundial if someone else has done the hard work, or at least the mathematics, for you.

There is a website where you can type in your latitude and longitude and whether you would like 'daylight saving', as well as the colour in which

you would like your sundial to be printed. You can even choose whether you would like Arabic or Roman numerals. This will produce a PDF file that you can save and print out and then you are ready to assemble your sundial. Print it on heavy paper or even card if your printer can handle it.

You could use this as a school project or to keep youngsters busy during school holidays, or as fun for yourself. The more accurately you assemble it and set it up, the more accurate the readings will be. This project is accurate to 15 minutes, which is the time it takes to make it!

For the PDF generator, please go to analemmatic.sourceforge.net/cgi-bin/papercraft.pl. If you live in the UK or Western Europe, you'll need to enter your latitude and longitude, as it doesn't recognise European postal codes. Have fun making and using your sundial.

Tips & tricks

Decide on DST or UT

You need to decide whether you want Daylight Saving time or Universal Time showing on your sundial.

Try out HTML colour codes

The default is for a black and white sundial but you can input HTML colour codes to change this.

Choose your numeral type

You can choose from Arabic (normal numbers) or Roman Numerals when making your sundial.

Use heavy paper or card

Print the sundial on heavy paper, or glue it to heavy card before you assemble it.

Fold - don't cut!

The gnomon needs to be folded, not cut, so score along the dotted lines with a sharp (but not too sharp!) point.



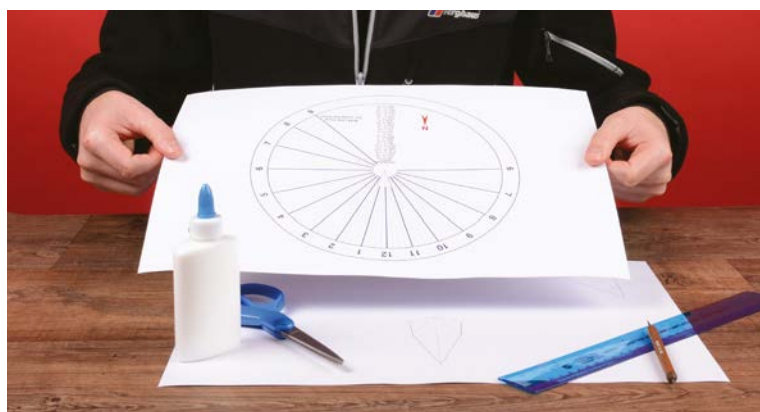
Making and using your sundial

Once you've made the device, you need to set it up carefully to show the right time

Now you have your sundial ready for action, you'll need to line it up to true north - or true south if you are in the Southern Hemisphere. If you're using a magnetic compass, make sure that you allow for the offset of the magnetic pole from your location - you can check this on a good survey map.

Place the sundial on a level surface such as a sunlit table, make any small adjustment necessary and enjoy telling the time by the Sun. Detailed instructions on how to create and set up the sundial can be found at www.instructables.com/id/15-minute-paper-craft-sundial/.

Send your photos to
space@spaceanswers.com



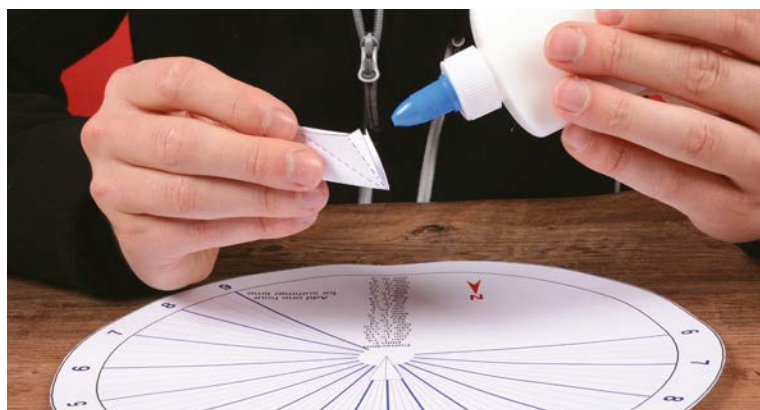
1 Print your sundial

Once you have created it online, print off both sheets of the PDF file and cut out the sundial. Glue it to some card for strength.



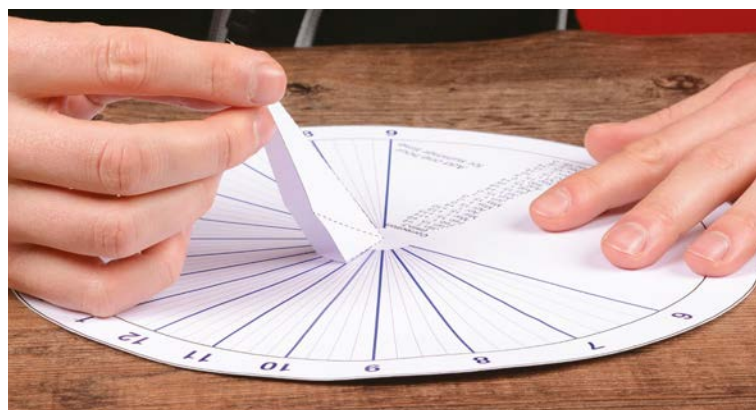
2 Score the gnomon

Score the lines on the gnomon, the part of the sundial that casts the shadow, with a fairly sharp point but do not cut it.



3 Fold and glue

Fold the gnomon in half as accurately as you can and glue it together. Leave it to dry before attaching it to the sundial.



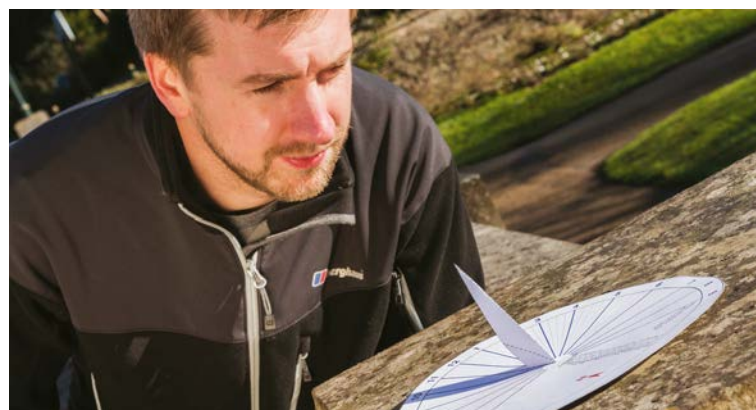
4 Attach the gnomon

Fix the gnomon to the sundial with glue, making any necessary adjustments before the glue is dry.



5 Align the sundial

Place your dial on a flat surface in the sunlight and align the 'N' arrow with true north - or the 'S' with true south if you're in the Southern Hemisphere.



6 Read the dial

You can read the time on the sundial by looking for the edge of the shadow furthest from the gnomon. Enjoy telling the time with your creation!



The Northern Hemisphere

Turn your binoculars, telescopes and unaided eyes to the March skies - there's plenty on show

Look to the north this month and there's plenty of objects to keep you occupied. In particular, the galaxies and star clusters of Cassiopeia (The Vain Queen) and Cepheus (The King) - and heading northwest to Perseus (The Hero) and Auriga (The Charioteer) - offer easy pickings for observers of the night sky with binoculars and telescopes.

Look to the southwest for a similar setup, with open star clusters scattered

throughout the constellations of Monoceros (The Unicorn), Orion (The Hunter) and Puppis (The Poop Deck), displaying the occasional galaxy for the telescope owner.

If you prefer to gaze upon the night sky without an optical aid, Capella, shining at magnitude 0, is noticeable in Auriga in the northwest, while Lyra hosts the stunning Vega, also at magnitude 0, in the northeast.

Using the sky chart

This chart is for use at 10pm (GMT) mid-month and is set for 52° latitude.

- 01 Hold the chart above your head with the bottom of the page in front of you.
- 02 Face south and notice that north on the chart is behind you.
- 03 The constellations on the chart should now match what you see in the sky.



Magnitudes

- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

- | | |
|-------|-----|
| ● O-B | ● G |
| ● A | ● K |
| ● F | ● M |

Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies

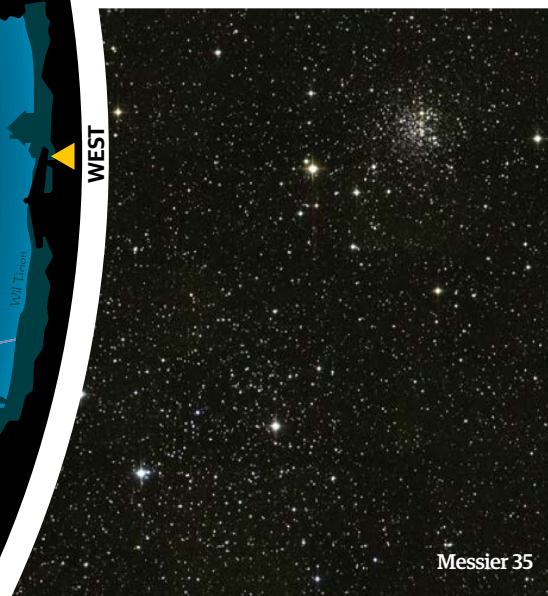
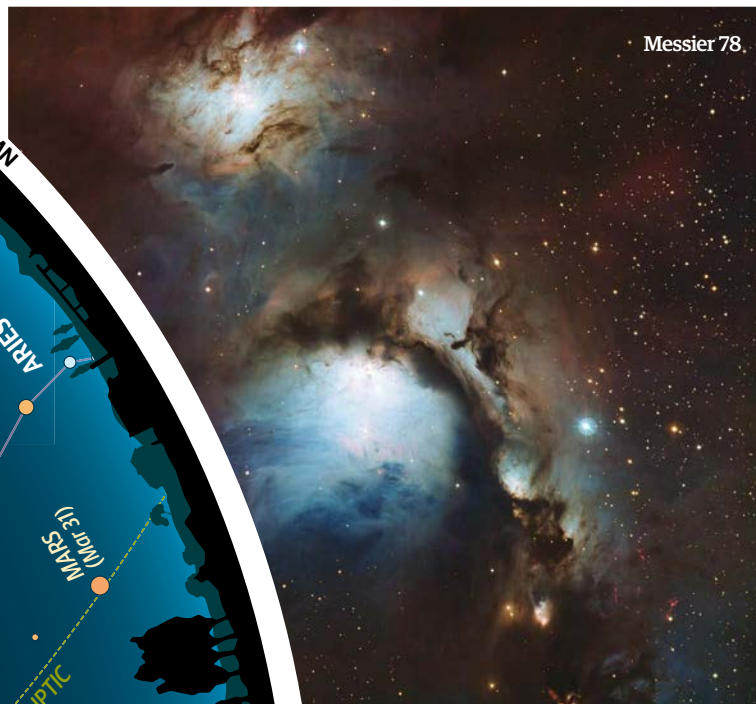
EAST

SE

Observer's note:

The night sky as it appears on 16 March 2017 at approximately 10pm (GMT).

The Northern Hemisphere





STARGAZER

Me & My Telescope

Send your astrophotography images to space@spaceanswers.com for a chance to see them featured in **All About Space**

Mohammad Mireskandari



Saveh, Iran

"The star trails I captured show the passing of time over an old caravanserai in Iran. These buildings

were roadside inns where travellers could recover from journeys they had embarked on during the day. Imaging conditions were ideal and I shot the sky using a Nikon D7000 and a Tokina AT-X Pro 11-16mm lens."

Star trails over an old caravanserai in Iran

Patrick Gilliland



Worcestershire,
UK & Calar Alto
Observatory, Spain
Telescope: Officina
Stellare RH 200
Astrograph, Borg
125 SC refractor,

Takahashi 106, Astro-Physics AP305

"I always had an affinity with dark nights as a child, sitting looking in amazement at all the stars within our galaxy, the Milky Way. In recent years, I decided to get much more involved in astronomy and began a hobby in astrophotography. I am now producing some very nice images - particularly of nebulae - as showcased here."

VdB 141



www.spaceanswers.com



Frank Bradshaw & Jason Howells

Horsham, West Sussex

Telescope: Sky-Watcher Explorer-150P



"I have been a keen amateur astronomer since I was about ten years old, using binoculars and small telescopes to provide insight into the night sky for friends

and family, but I could never really afford a proper telescope. A few years back, my friend was lucky enough to win a reasonable amount on the Lottery in a syndicate and one of the first things he did was buy me a 6" telescope! I took this image a few weeks back and was kindly helped with the image processing by Jason Howells of the Worthing Skywatchers group, using PixInsight."

Orion (M42) and Running Man Nebula (NGC 1973, NGC 1975 and NGC 1977)

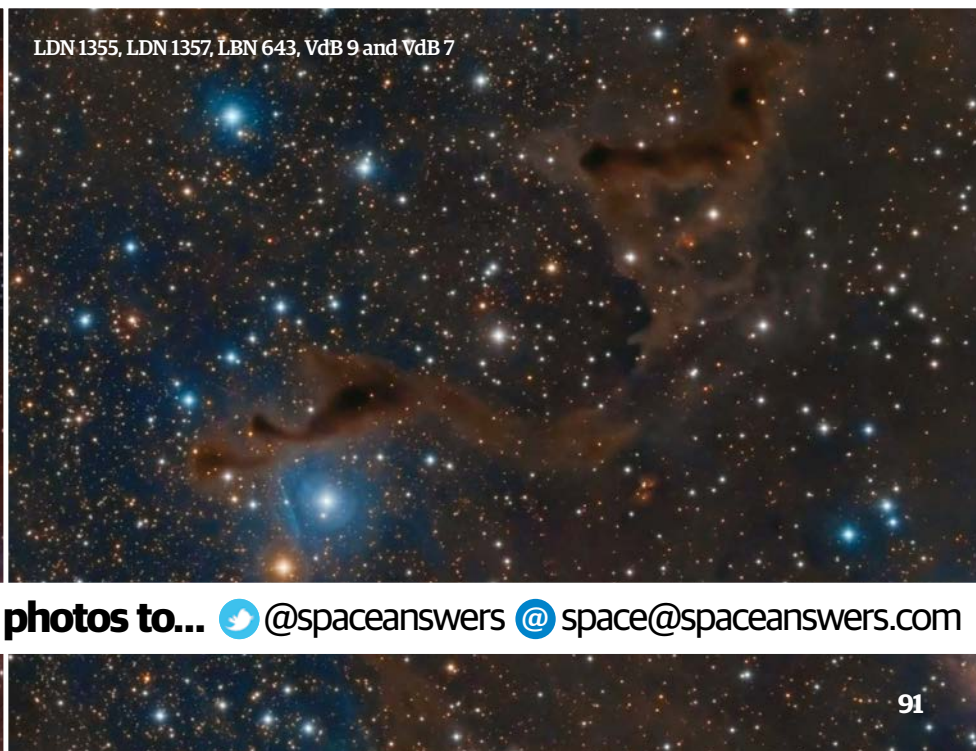
STARGAZER
Me & My Telescope



NGC 6888



LDN 1355, LDN 1357, LBN 643, VdB 9 and VdB 7



Send your photos to... @spaceanswers @space@spaceanswers.com

Meade Infinity 60AZ

Perfect as an introduction to astronomy, this beautifully finished telescope is suitable for observing the lunar surface and the planets

Telescope advice

Cost: £250

From: Hama UK Ltd

Type: Refractor

Aperture: 2.4"

Focal length: 31.5"

Best for...



Beginner



Small budget



Planetary viewing



Terrestrial observing



Lunar viewing



Families

Starting out on the right foot is essential in astronomy and this introductory telescope from Meade Instruments ensures that the beginner is fully equipped for their first night under the stars. It comes complete with low-power (26mm) and high-power (6.3mm) Plössl eyepieces for a variety of viewing situations, along with a 2x Barlow lens, which doubles the magnifying power for each of the eyepieces. We are pleased to see that a red-dot finder - rather than an optical finderscope - is supplied for effective touring of the night sky. This ensures that fainter stars can be used for star hopping with ease, meaning that the observer doesn't need to stick to the brighter stars from areas with less-than-ideal conditions.

We are also pleased to see that Meade is realistic and honest about the Infinity 60AZ's capabilities - many a time we have seen Hubble Space Telescope images splattered across the packaging of telescopes by the telescope manufacturer, and beginners can often be fooled into thinking that they'll get NASA space telescope views through an amateur instrument. Due to its aperture, the Infinity 60AZ is best used for observing

the rugged lunar surface, the planets - namely Saturn, Jupiter, Mars and Venus - and, provided the viewing conditions are good, some of the brighter deep-sky objects. Setting up of the refractor is extremely intuitive, however, an easy-to-follow instructions manual is provided along with AutoSuite planetarium software. At present, this software can only be run on Windows.

The alt-azimuth mount and tripod already come fully assembled out of the box and the overall setup is impressive for a telescope in such a low price range. The tripod legs are easy to adjust with easy-to-use tabs to lock them in place. If you're not fully satisfied with the sturdiness of the telescope, then a small Phillips' head screwdriver and wrenches are supplied for tightening up those loose areas.

The Infinity 60AZ's objective lens is beautifully finished with a bluish-green anti-reflective coating that appears to be even. Three evenly spaced separation pads, commonly associated with refractors with air-spaced doublet objectives, could also be seen when we peered down the telescope's tube. As with

all of Meade's telescopes, a substantial dew shield has been manufactured and, similar to the lens cells, is comprised of tough plastic.

Both inside and outside of the tube are well painted and we were appreciative of the exquisite blue

Low-power (26mm) and high-power (6.3mm) eyepieces allow for good observations of a selection of targets, while a Barlow lens magnifies the view by 2x



A copy of AutoSuite planetarium software is supplied, helping novice astronomers to tour the night sky from their own home



Clear and bright views can be had through the Infinity 60AZ, thanks to a bluish-green anti-reflective coating

The overall setup of the Infinity 60AZ is impressive given the low price of the instrument. It is extremely portable, making it ideal for families

"The Meade Infinity 60AZ is a robust telescope that's ideal for the whole family"

finish, which makes it stand out from the much-more-common black and white tubes often manufactured by other telescope makers. The previously-mentioned red-dot finder is ideal for any beginner's instrument; be aware that these finders can run batteries low quite quickly, so be sure to switch it off when you've located your target. The build of the eyepieces is sufficient and, when slotted into the 1.25" holder, ensure that the scope isn't too 'back heavy'.

Using the star diagonal is a pleasant experience, angled in such a way that peering through the eyepiece is comfortable. Using the 26mm eyepiece during the day and on a line of trees, we noted that the field of view isn't entirely crisp - a flaw that comes about from using a prism that's too small for a telescope's optical system. However, given that the Infinity 60AZ is aimed at those new to the hobby, this isn't a huge problem for basic observing. Early February brought thick clouds

and rain, meaning that we were forced to look for gaps in the cloud to test the Infinity 60AZ's mettle. We were rewarded with views of Venus, Mars and the Moon as they hung close together in a cloud-free southwest during the early evening.

Views of the lunar surface were good through the telescope and, on the whole, were wonderfully crisp and clear, as craters stood out beautifully. There were hardly any problems with glare but there was - as with many refractors - a touch of blue-purple colour fringing. We also advise using a Moon filter when the Moon is full to lessen the intensity of light coming through the telescope.

Slewing effortlessly to Venus, we did have a problem with colour fringing due to the planet's intense apparent magnitude of -5.4, however, we were (just about!) able to achieve a small view of the planet at its phase of 40 per cent. Meanwhile, observations of Mars were good through the Infinity

60AZ, as it appeared as a featureless salmon-pink disc in our field of view.

With Ursa Major directly overhead, we were keen to split double stars Alcor and Mizar. Using the mount to angle the scope's tube upwards, we did notice that the mount's handle swings downwards, covering the closest eyepiece hole in the accessory tray - this is a small niggle, but can be overcome by simply not putting an eyepiece in this part of the tray. Views of the Pleiades star cluster, also known as Messier 45, in the constellation of Taurus were pleasant, with the optics revealing the member stars as clear blue-white points of sparkling light. A robust telescope that's ideal for the whole family, the Infinity 60AZ is ideal for those looking to get started in stargazing without breaking the bank.

The Infinity 60AZ features a beginner-friendly mount

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along with a Porro prism design and BaK4 prisms, AstroBinoculars deliver both comfort and superior light transmission.

To add to your stargazing equipment, and courtesy of Hama UK and Meade Instruments, we're also giving away *Philip's Guide To The Night Sky*, *Philip's Deep Sky Observer's Guide* and *Dorling Kindersley's Guide To Stars And Planets*, in order to help you find your way around the night sky.



To be in with a chance of winning, all you have to do is answer this question:

What was the first object to be put in the Messier catalogue?

A: Horsehead Nebula

B: Sombrero Galaxy

C: Crab Nebula

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Book

Astronaut Owners' Workshop Manual

Cost: £22.99 (approx. \$28.76)

From: Haynes Publishing

On first impressions, it can be difficult to see how *Astronaut Owners' Workshop Manual* fits into the pre-existing manuals published by Haynes. However, on reading into the meatier sections of this manual, which takes the reader through what's involved in becoming an astronaut, this book changes the pace from the usual spacecraft, rockets and rovers manuals that Haynes usually publish. Written in an accessible style for the layperson, the reader is taken through the training for each of the different astronaut roles - from pilot through to Moonwalker - and is informed of the different kinds of missions where astronauts are required, such as living on board the International Space Station and sub-orbital as well as future missions to Mars.

Featuring schematic diagrams and photographs of the whole astronaut training and flight experience, *Astronaut Owners' Workshop Manual* captures a whole new level of the excitement of human spaceflight, featuring astronaut biographies and personal thoughts from the astronauts themselves for a rounded and colourful read. Chances are that if you are keen on spaceflight, then you will be familiar with the contents of this book. However, we think it's the fine technical details about how human spaceflight actually works that will keep the more knowledgeable readers engaged. A very well made piece of work from Haynes!



Software

SkyGazer 4.5.7

Cost: \$49.95 (approx. £39.97)

From: Carina Software & Instruments Inc

Offering all of the necessary information to make touring the night sky a breeze, SkyGazer 4.5.7 is ideal for budding astronomers. This planetarium software is compatible with Windows and Mac OS X systems for optimum versatility.

Running the software, it does seem quite 'primitive' compared to others on the market and - for the price - SkyGazer needs an upgrade on its newest version (which was created back in 2010!) We enjoyed the close-up three-dimensional views of the planets in our Solar System, as well as the database that contains digestible information on these worlds and their moons, along with the many asteroids and comets. A fun feature, which Carina Software has packed into SkyGazer, allowed us to recreate historical sky simulations - going back to 1170 AD, we were able to see Mars appear to pass in front of Jupiter. Unfortunately, this software does lack interactive tours but there are animations that teach the user about astronomical concepts such as the motions of the planets and how eclipses work. SkyGazer integrates the NASA Jet Propulsion Laboratory's planetary ephemeris, which computes the positions of the planets. However, given that you can get this free from the internet, this software is very much on the expensive side and lacks the bells and whistles that come with other planetarium software in its price range.

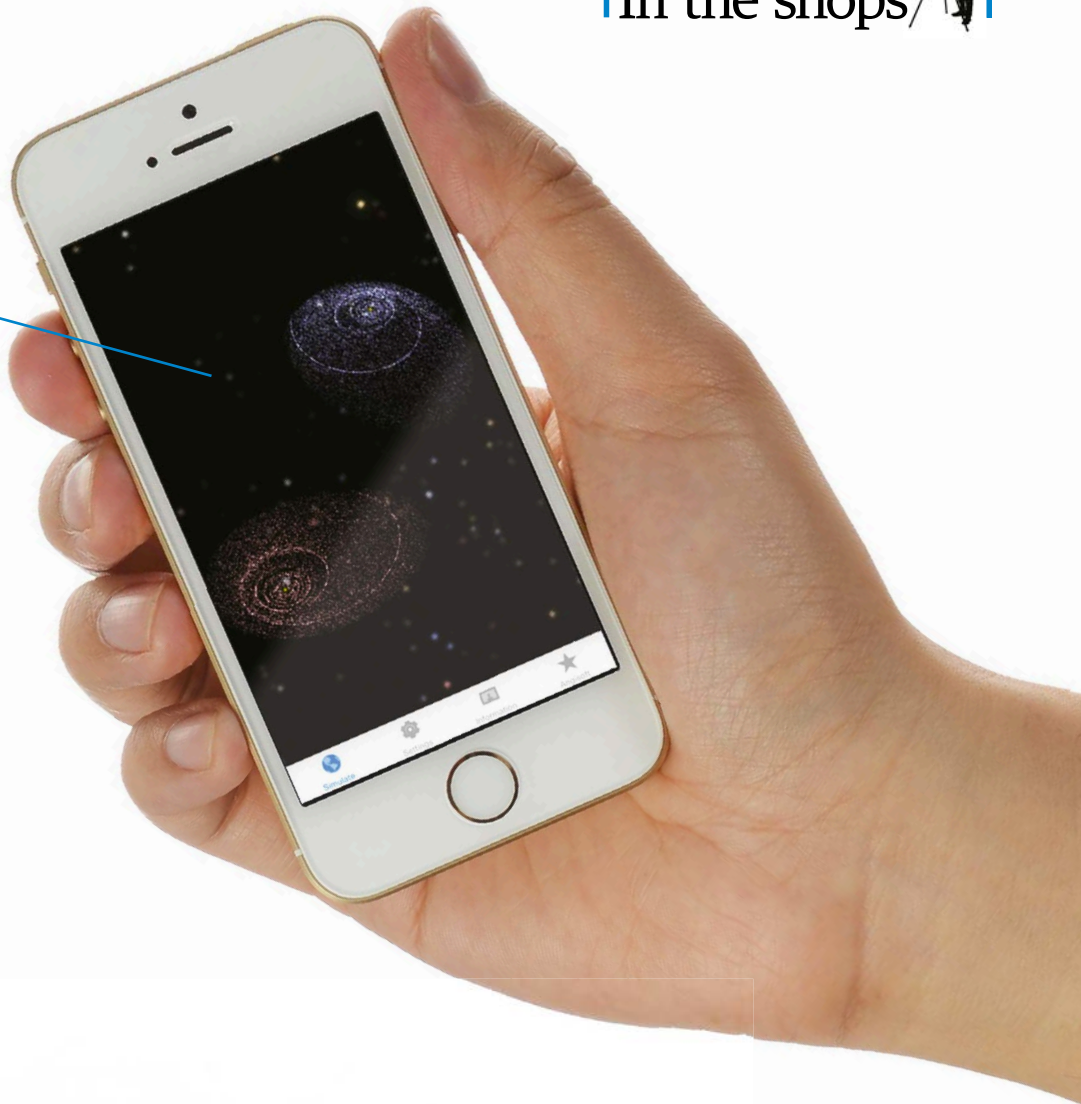
App **Galaxy Collider 1.52**

Cost: £0.99 (\$1.99)

From: Angisoft

Want to be a master of galaxy smashing? The Galaxy Collider smartphone app is the software for you. By simulating the physics of interacting galaxies, this app is quite an accurate simulation of what happens when these giant structures, packed with stars, merge. Galaxy Collider is great fun to use and allows the user to alter the size and number of galaxies in the simulation before smashing them together. On a couple of occasions though, we discovered that there were a couple of glitches in the running of the app - for example, after a period of time had passed, the galaxies seemed to reset even if we hadn't collided the structures. On these occasions, which were quite regular, we were forced to restart the app.

We also discovered that there is no way to put the galaxies into a 'slow motion' setting - a promised function - which we still couldn't resolve from the help section of the app. The general look of the app isn't great, but given the complexity of the app, this is perhaps one of the last things the developer was worried about. Nevertheless, we think putting a 'wow' factor into the appearance of the graphics may encourage more downloads.



Filters **Optolong Venus-U & UHC filters**

Cost: £72.00 (approx. \$89.51)

From: 365Astronomy

If there's one thing that keen observers of the night sky should own - after a telescope or binoculars, of course - it's a set of filters for the optimum observing experience. Using a selection of filters from a range of manufacturers, we've discovered that it's difficult to go wrong with these essential pieces of kit.

However, on trying out the Optolong filters, we have to say that they are a cut above the rest, from their build through to how they fare during observations. These filters are expensive but if you're looking for crystal-clear, enhanced views, without the need of Photoshopping your images, then Optolong filters are a worthy purchase. Venus was visible during the early evening, allowing us to put the Venus-U filter to the test. Without filters, this -5.5-magnitude world was so bright that it was difficult to see any detail. Turning the telescope to the planet with the filter attached, we quickly appreciated the change in contrast. Through this Optolong filter it was extremely easy to pick out details, including subtleties on the planet's cloud cover along with a clear, obvious view of its phase. The UHC filter was just as impressive, enhancing our views of a selection of deep-sky targets - in particular, the Orion Nebula - effortlessly. Superb coating allowed for a dramatic improvement in contrast and in particular, our view from areas of modest light pollution was improved, meaning that we weren't forced to travel to a darker site.





The Moon's Humason crater is named in honour of Milton L. Humason

© J. R. Eyerman/Getty Images

Milton L Humason

The self-educated former mule driver whose research helped discover the expanding universe

Sometimes simply having an interest in a subject can put someone on the path to becoming a true star. That certainly proved to be the case with Milton L. Humason, who began working as a janitor at Mount Wilson Observatory, Los Angeles, shortly after it was completed in 1917. His subsequent appointment as a night assistant at the observatory led him to become a staff member. He then went on to play a key role in a crucial space discovery, cementing his place as a hero of space.

Humason was not, it is fair to say, a particularly remarkable child. Born in Dodge Center, Minnesota, in 1891, he took a year away from school at the age of 14 and never went back. Instead, having had his head turned by the splendid surroundings of Mount Wilson during a summer camp, he spent five years as a mule driver, transporting building materials from the Sierra Madre mountain range to the site of the astronomical observatory during its construction. There he met Helen Dowd in 1911, the daughter of the observatory's chief engineer, and they married shortly afterwards. He then moved east of

Los Angeles to La Verne and became a ranch foreman.

But his decision to take a job as janitor at the Mount Wilson Observatory changed his life. Humason's diligence and skill had caught the eye of George Ellery Hale, the solar astronomer who founded the observatory. By 1919, Hale had offered the 28-year-old a staff job and while the decision didn't go down well among the astronomers who objected to having a school dropout working among them, Humason soon won his detractors over.

In the 1920's he was assigned to work with Edwin Hubble in studying the spectral redshift of galaxies. This was good fortune. Hubble recognised the presence of galaxies beyond our Milky Way and he began gathering data that proved the universe was expanding. He compared the distance estimates to galaxies with their redshifts and noted that the galaxies furthest away were moving faster than those closest. Hubble's Law was formulated, stating the radial velocity of a galaxy was related to its distance and that the galaxies were moving away from each other.

Humason's work was instrumental in allowing Hubble to reach this conclusion, putting in the behind-the-scenes work that made success ever swifter. He had developed a technique that optimised the photographic exposures and plate measurements, and it allowed the faintest of galaxies to be pictured and observed. He was also meticulous in studying the plates for hours and hours in the hope of coming across something startling and it earned Humason great respect. So impressive was his work - which also enabled better study of supernovae and faint blue stars - that he was awarded an honorary doctorate from the prestigious Lund University, Sweden, in 1950. He continued to work for seven more years before retiring.

Yet his work wasn't entirely done. On 1 September 1961, he discovered Comet C/1961 R1. This non-periodic comet - known as Comet Humason - had a perihelion beyond Mars' orbit, yet there was some disappointment, not least in the missed opportunity of being the discoverer of Pluto. The dwarf planet is said to have appeared within a defected area of the plate causing him to miss it. Clyde Tombaugh took the honour of discovery more than a decade later instead. Still, Humason's work remains remarkable, contributing greatly to our understanding of the universe. Having died at the age of 80 on 18 June 1972, in Mendocino, California, he left a legacy that will never be forgotten.

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Future Publishing Ltd
Richmond House, 33 Richmond Hill
Bournemouth, Dorset, BH2 6EZ
☎ +44 (0) 1202 586200
Web: www.spaceanswers.com
www.greatdigitalmags.com
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Editorial

Editor Gemma Lavender
gemma.lavender@futurenet.com
☎ 01202 586209

Editor in Chief James Hoare

Designer Jo Smolaga

Assistant Designer Laurie Newman

Production Editor Amelia Jones

Research Editor James Horton

Photographer James Sheppard

Senior Art Editor Duncan Crook

Contributors

Stuart Atkinson, Ninian Boyle, Jaspal Chadha, Paul Cockburn, David Crookes, Robin Hague, Dominic Reseigh-Lincoln, Giles Sparrow, Luis Villazon

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Advertising

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Ad Manager Gary Simpkins

☎ 01225 687 394
gary.simpkins@futurenet.com
Account Manager Will Sandilands
william.sandilands@futurenet.com
☎ 01225 687 503

Sales Executive Samantha Novata
samantha.novata@futurenet.com
☎ 01225 687 374

International

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Head of International Licensing Cathy Blackman
☎ +44 (0) 1202 586401
cathy.blackman@futurenet.com

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Head of subscriptions Sharon Todd

Circulation

Circulation Director Darren Pearce
☎ 01202 586200

Production

Production Director Jane Hawkins
☎ 01202 586200

Management

Finance & Operations Director Marco Peroni
Creative Director Aaron Asadi
Editorial Director Ross Andrews

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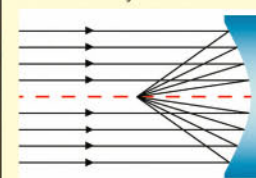
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